CONSUMER HEALTH BENEFITS THROUGH AGRICULTURAL BIOTECHNOLOGY: AN ECONOMIC EXAMINATION OF OBSTACLES TO COMMERCIAL INTRODUCTION

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ABSTRACT

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The first generation of agricultural crops developed using biotechnology have offered the primary producers of the crops agronomic benefits. Some consumers have resisted accepting this technology because of concerns with food and environmental safety, and ethical issues that arise from the processes that are involved in developing these products. The second and third generation of agricultural biotechnology are being developed to offer products with direct benefits to consumers. The focus of this thesis is the second generation, which have added health benefits. Specifically, the obstacles to commercialization of functional foods derived through biotechnology are examined.

The three factors which have the potential to set back commercial introduction of functional foods derived through biotechnology are government regulatory uncertainty, consumer aversion and brand risk, and gaining access to intellectual property. The regulations governing functional foods are examined to show the regulatory ambiguity that exists in Canada. Comparisons are drawn to other nations. Literature that focuses on consumer aversion to agricultural biotechnology is reviewed, along with consumer preference studies with regards to genetically modified (GM) foods with and without health benefits. Transaction cost economics literature is used to analyse the problems

related to gaining access to intellectual property and the resulting supply chain implications.

Three separate theoretical models are developed to examine each of the three factors separately. Government regulatory uncertainty is incorporated into an expected profit model to show the effects of increased uncertainty on the expected profit from a new technology. A heterogeneous consumer preference model is used to show the effects of changing consumer preferences on the market share of the firm introducing the GM functional food to the market. Simulation analysis using this model shows the effects of changing variables on the market shares of three products in the market. Finally a stylized model of the vertical market shows the effects of increased transaction costs incurred in gaining access to intellectual property on the rent that is available for distribution throughout the supply chain.

The results show that these factors could be an obstacle to commercial development of functional foods derived through biotechnology. When the three factors are combined, the rent available for distribution is important for the success of the supply chain. Multiple bilateral monopoly negotiations cause this rent to be less than optimal. Increased levels of government regulatory uncertainty, consumer aversion and brand risk, and costs gaining of access to intellectual property decrease the expected rent available for distribution. This could be a problem facing developers of functional foods derived through biotechnology.

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

Agricultural production in western Canada and throughout the world has traditionally been commodity based. Researchers have consistently made improvements to crops through breeding techniques that lead to higher crop yields. *Ceteris paribus*, the increased yield leads to higher production levels and a downward trend in prices. The grain handling industry has adapted to be able to handle the large volumes of homogenous grain. Consistent improvements in technology reacting to this trend have led to the low cost bulk grain production and handling that exists in North America today.

One of the major trends that is occurring in food markets is a greater demand from consumers for food safety and quality. As a result of the scientific community gaining an increased understanding of the links between diet and disease prevention, consumers have begun to demand certain health attributes from their food (Health Canada, 2001). Demand for specific health attributes in food has been made possible by increased levels of consumer income. Stronger consumer preferences have led to a shift away from the traditional minimum cost commodity production. Producers and manufacturers are now attempting to gain returns from differentiation and specialization to fill niche markets.

Consumer concerns for food safety have been shown towards foods that are produced from genetically modified (GM) crops. These crops have been modified through transgenics, which is the transfer of genes from one species to another. Widespread aversion to these crops, especially in the European Union (EU) has shown that consumers are concerned with credence characteristics in the food they eat. Certain credence characteristics can be used by firms for product differentiation, though the characteristic cannot be identified by the consumer before, during or after consumption (Feddersen and Gilligan, 2001). In the case of GM crops, some consumers believe that the safety of these crops has been inadequately proven (both food and environmental), have other ethical problems with the methods used in the process of modification, or they simply distrust the influence of large multinational corporations on what they eat (Hobbs and Plunkett, 1999). These consumers would not necessarily be appeased if the price of GM foods were lower. They tend to support labelling GM foods and segregating them from those products that are GM free.

The aversion to the first generation of GM foods, which solely contain input traits, is logical in many ways because the consumers are not receiving a significant portion of the benefit from the technology. Moschini (2001) states that theoretically 44% of the economic efficiency gains from Roundup Ready Soybeans go to the seed innovators. The consumers in this model gain 40% through a price decrease and the producers 16% of the total efficiency gains. However, these are potential benefits not considering consumer preferences, and the actual price benefit passed on to the consumers. Gaisford et al. (2001) provide the explanation that the demand reduction from the adverse quality effect outweighs the beneficial price effect from the adoption of GM

crops. There has been little calculation of price effects caused directly from biotechnology; however, a high consumer aversion combined with a low price effect could lead to a net consumer loss from biotechnology (Giannakas and Fulton, 2004). It could be argued that many consumers are unaware of the potential environmental and health benefits from less pesticide use from producing GM crops, and lower contamination by fungal spore development resulting from insect damage (TFILSI, 2004). Although these benefits may be largely unrecognised by consumers, future generations of GM foods promise traits that directly appeal to the consumer market.

The second and third generation of GM products are being created to contain output traits that give additional benefits to consumers. The second generation of GM crops includes functional foods and nutraceuticals or natural health products (NHPs). There is potential for developments in GM functional foods and NHPs[1] to provide products that offer additional health benefits to consumers. Functional foods and NHPs exist currently that are not GM, but GM technology has the potential to enhance functional traits in conventional foods, and produce new NHPs. These range from omega-3 fatty acids in oilseeds, to non-allergenic peanuts, to plant-produced pharmaceuticals that can be produced at a potential cost advantage relative to those produced from animal cell cultures. For this reason, plant produced pharmaceuticals may allow for cheaper provision of pharmaceutical products to consumers.

The preferences of consumers are important factors to determine the feasibility of the next generation of GM foods. The preferences of consumers towards GM foods have been well documented. Some studies have specifically assessed consumer willingness to

[1] Products considered to be nutraceuticals are regulated in Canada under the broad category of Natural Health Products

pay for GM functional foods (Larue et al., 2004; Lusk et al., 2002). Both of these studies showed that consumers had a willingness to pay a premium for GM foods that offered consumers functional characteristics.

However, individual consumer preferences change over time because of increased knowledge and information. Firms responsible for the introduction of GM functional foods may realize that new product introductions based on current consumer perceptions carry risk. For this reason, firms may be concerned with the potential impact on their entire brand offering caused by positive or negative consumer experience with the new food.

The potential benefits of the second generation of GM products have been emphasized by lifescience firms for several years. It is known that these products have been under development for some time. However, the failure of any significant entry of GM functional foods to the market suggests that there may be additional problems preventing the commercialization of these products. The supply chain relationships for GM functional foods and NHPs are substantially more complicated than those in traditional foods. In order to further develop new products based on existing technologies, firms could be required to purchase licenses to access the technology or genetic resource. Throughout this thesis, this will be referred to as gaining access to intellectual property. In the case of the first generation GM products this has been relatively simple because there is normally a single critical transgene involved. In the case of the second generation of GM foods, there could be several critical transgenes involved. For each critical transgenic manipulation, licenses may have to be negotiated for the promoter, selectable marker, transformation method and the expressing protein of

interest.[2] The increase in intellectual property in the second generation of GM foods means that the search and negotiation costs could become quite high because of multiple negotiations. Also, the distribution of rents becomes a concern when multiple monopolies are involved in the negotiations. The problems negotiating the distribution of rents in this case could lead to the classic hold-up problem.

The premium that consumers are willing to pay for GM functional foods might not be sufficient for food manufacturers and lifescience firms to make an investment. The premium must be large enough to provide adequate rent to compensate for extra investment by food manufacturers and lifescience firms. The risk of a small percentage of the population becoming vocally opposed to the technology and driving away demand might be too large of a risk to take for the food manufacturers who receive only a portion of the benefit.

1.2 Problem identification

This thesis will examine the obstacles preventing the commercialization of GM functional foods. While there are many potential obstacles that could set back commercialization, this study deals with government policy uncertainty, consumer aversion and branding, and access to intellectual property. The thesis will provide a detailed description and theoretical model of how these factors create obstacles to

[2] The *promoter* is the region of the DNA where RNA polymerase binds in order to initiate transcription. The *selectable marker* is a gene whose expression allows the identification of cells that have been transformed with the marker gene. The *transformation method* is a method of modifying the genome with DNA from a cell of a different genotype. Finally, the *expressing protein* is the protein produced from the previously mentioned coding sequences (Everythingbio.com, 2005)

commercialization. We will then explore how these obstacles will affect development of the future supply chain in a GM functional food industry.

1.2.1 Government policy uncertainty

When the first generation of GM crops were proceeding through the regulatory stages leading to commercial introduction in the mid 1990s, policymakers were concerned mainly with the safety of these products. It was not until later in that decade that widespread international consumer aversion to these products led to increased scrutiny over the way in which these products were approved. Many countries, including Canada, claim to base acceptance on the principle of substantial equivalence[3]. Other countries, most notably members of the EU, responded to consumer aversion by instituting a complete moratorium on new GM products in 1998 that lasted until 2004. This has recently been replaced by low tolerance levels for GM contamination and mandatory labelling requirements.

Uncertainty within government policy can be a concern to those firms developing a new technology. Monsanto was recently affected by policy uncertainty. The lifescience multinational has delayed the development of glyphosate-tolerant wheat varieties in Canada, partially as a result of difficulty gaining approval from regulators. It was widely believed that this delay was in response to lobbying efforts by farm groups and agricultural organizations such as the Canadian Wheat Board who feared a large reduction in demand for Canadian wheat if glyphosate-tolerant varieties were approved.

[3] The OECD (1993, pp.11) defines substantial equivalence as follows: *"...knowledge that a new food or food component(s) was derived from organism(s) whose newly introduced traits have been well-characterised, together with a conclusion that there has been reasonable certainty of no harm as compared with its conventional or traditional counterpart, means that a new food or food component(s) can be considered substantially equivalent."*

Although many farmers and consumers welcomed this decision by Monsanto, it provides a good example of the uncertainty that exists in the regulation of these products. As a result of this uncertainty, firms may be hesitant to invest funds in the development of new products that could meet resistance at the regulatory approval phase.

GM functional foods could face a similar problem because of the process used to genetically alter conventional varieties to express extra health benefits. The issue is further complicated by the fact that if the food is altered to express altered nutritive content, it might no longer be viewed as substantially equivalent. Finally, in order for GM functional foods to communicate their value to the consumer, it will be important that certain claims are allowed. Current ambiguity in functional food regulation means that the types of claims that will be allowed on functional foods are not clear to manufacturers. Chapter two will explain the current status of these regulations, and explain the uncertainty that exists. With this uncertainty, investment into GM functional foods could be forestalled, which will be modelled in chapter three.

1.2.2 The consumer aversion and brand risk problem

Ultimately, the reaction of consumers to GM functional foods could be the most important factor in determining the success of these products. Consumer preference literature shows that there is a proportion of consumers that are willing to pay a premium for GM food if it provides them with some health benefits (Larue et al., 2004, Lusk et al., 2003). There are several other factors that consumers take into consideration when purchasing food besides the nutritional content. Another important factor may be brand loyalty to specific manufacturer brands.

Food firms contemplating venturing into manufacturing GM functional foods will be interested in the consumers' perception and willingness to pay. However, there are several other factors that will be examined before a food manufacturer invests in developing GM functional foods. Considering the high level of concentration within the food manufacturing sector, there is a strong possibility that a relatively large and diverse firm will be involved in production of these foods. These firms will want to consider the reaction of their consumers to the introduction of GM functional foods. In particular, these firms will be interested in how the introduction of a new GM functional food will affect the brand as a whole. If there is a negative reaction from the segment of the population that is strongly opposed to GM technology, it could negatively affect the brand value. Chapter 3 will model the possible outcomes of introducing a GM functional food. Depending on the size and influence of this group, backlash towards the brand as a whole could outweigh the benefits received from the consumers who purchase GM functional foods.

1.2.3 Access to intellectual property

The third factor that could set back the commercial introduction of the second generation of GM foods is the difficulty that firms developing functional foods have in obtaining the licenses necessary to gain access to intellectual property. As explained earlier, there are several components of the GM food that must be licensed in order to legally develop new products using the technology. Prior to commercial introduction of a new product, the firm must determine what pieces of technology within the product are patented and who holds the patent. After this information is known, the firm must

negotiate a license for the use of the technology. All of these processes carry transaction costs.

The transaction cost economics literature that relates to the negotiation of licenses is reviewed in chapter two. Chapter two also explains some possible institutional solutions to the high transaction costs in the market for licenses to use intellectual property. Finally, the supply chain effects of access to intellectual property are reviewed. Chapter 3 provides a theoretical model of the effects of increased transaction costs on the supply chain for GM functional foods.

1.3 Summary

The introduction to this thesis presents the three factors that pose obstacles to the commercialization of GM functional foods. The three factors: government policy uncertainty, consumer aversion and brand risk, and access to intellectual property could cause a set back individually. The combination of these factors in the supply chain suggests the problem could be acute. Chapter two offers a background to the problem. Following the background, the literature detailing the three factors is discussed. Chapter three provides a theoretical framework to examine these problems separately. It also provides simulation analysis to show the effects on market shares of shocks to the modelled variables and parameters. Chapter four provides case studies using existing literature and interviews with those involved in the industry. These case studies are provided to identify examples of situations where the problems discussed are evident. The case studies identify past failures and successes that assist in identifying problems, and offer suggestions as to how to avoid the same problems in the future. Chapter five

provides a discussion linking the factors contributing to the delay of commercialization and offers predictions about the potential structure of the supply chain. Finally, chapter six provides a conclusion to the thesis.

CHAPTER TWO

INDUSTRY BACKGROUND AND REVIEW OF LITERATURE

2.1 Introduction

There are several issues in this thesis that must be explained in order to provide a background to the obstacles facing GM functional foods. First of all there is some confusion regarding the definitions of the terms that will be used throughout the thesis. Functional foods, nutraceuticals and natural health products are referred to often, but their distinct definitions are frequently confused. The first section of this chapter provides definitions of the terms.

Once the products are clearly defined, it becomes evident that a thesis focusing on functional foods, nutraceuticals and natural health products simultaneously would be quite a broad subject area to study. In order to draw more valuable conclusions, the remainder of the thesis will focus specifically on the obstacles delaying the commercialization of GM functional foods.

Following Section 2.2, the background to the problem is described in subsequent sections. The first factor considered is the regulations that exist in Canada, the US and the EU, along with the corresponding uncertainty. Specifically, the regulations concerning the types of claims that food manufacturers can insert on labels will be examined. Regulatory ambiguity, especially in Canada, could be a set back to commercial development of GM functional foods. Following this, the issues related to consumer

aversion and branding are discussed. Finally, another factor with the potential to impede commercial introduction of GM functional foods is the fact that the genetic commons that once existed internationally have been overtaken by patented genetic material. This means that in order for a firm to gain access to genetic material patented by another firm, they will probably have to negotiate licensing agreements. The process of obtaining the licenses required for commercialization could absorb much of the rents needed to justify the investment in the technology. The combination of the factors discussed in this chapter will provide a contextual background to explain why there has been no large-scale commercialization of functional foods. The purpose of the remainder of the thesis is to provide a deeper theoretical and empirical explanation of these issues.

2.2 Functional foods, nutraceuticals, and natural health products

The terms functional foods, nutraceuticals and natural health products are often blurred into one category. However, for the purposes of this thesis it will be necessary to provide a distinct definition of each product. Nutraceuticals and functional foods compete in different markets and target unique consumer characteristics, and are treated separately in this thesis.

Health Canada have defined nutraceuticals as follows,

> *A nutraceutical is a product produced from foods but sold in pills, powders, (potions) and other medicinal forms not generally associated with food and demonstrated to have a physiological benefit or provide protection against chronic disease.* (Health Canada, 1997, pp. 6)

The definition of a functional food, according to Health Canada is quite distinct from that of nutraceutical,

> *A functional food is similar in appearance to conventional foods, is consumed as part of a usual diet, and has demonstrated physiological benefits and/or reduces the risk of chronic disease beyond basic nutritional functions.* (Health Canada, 1997, pp. 6)

Natural Health Products are a combination of several types of products, including nutraceuticals, vitamins and minerals, herbal remedies, homeopathic medicines, traditional medicines such as traditional Chinese medicines, probiotics[4], amino acids and essential fatty acids (NHPR, 2003). The term natural health product seems to be a label that is unique to Canadian regulations. The regulations for natural health products do not include food, so functional foods are excluded.

At the retail level, nutraceuticals compete for market share with pharmaceuticals, supplements and vitamins. The claims made by nutraceuticals are more specific than those made on functional foods. The language used on the product labelling can be manipulated to distinguish between the two types of products. For example, a functional food would contain a label akin to "Helps to maintain a healthy blood-pressure" (Veeman, 2002). This type of label stresses that the functional food can help to maintain a healthy body; however, there are no measurable short-term results. A nutraceutical, on the other hand, would be similar to a pharmaceutical and use stronger language on the label such as, "Reduces blood pressure" (Veeman, 2002). The types of claims that are currently allowable in Canada are shown in sub-section 2.3.1, while an example of wording is shown in sub-section 2.3.2.

[4] A probiotic is defined in the Canadian Natural Health Products Regulations as, "…a monoculture or mixed-culture of live micro-organisms that benefit the microbiota indigenous to humans." (NHPR, 2003, pp. 1537).

2.2.1 Functional foods

Many of the foods that are consumed throughout the world provide the individual consuming the food with a type of 'function'. There is some disagreement about using the term functional foods, because all food serves some function (Health Canada, 1997). There are several traditional foods that contain functional properties.

Most functional foods contain phytochemicals. Phytochemicals are non-nutrient, physiologically active plant components which are present in plant materials in relatively small amounts compared to macronutrients (Unnevehr and Hasler, 2000). Lycopene is a well-known example of a phytochemical that is available by consuming tomatoes. Lycopene consumption has been shown to lower the risk of cancers such as prostate, breast, digestive tract, skin and lung (Hasler, 1998).

There are several other examples of functional foods. Cruciferous vegetables such as broccoli and brussels sprouts contain glucosinolates, a metabolite, which are synthesised from amino acids and may reduce the risk of cancer (Wang et al., 2002). Other potential cancer-fighting foods include citrus fruits, which contain a group of phytochemicals called limonoids; and beef, which contains omega-3 fatty acid and linoleic acid (SCC, 2004). The risk of cardiovascular disease can also be reduced through consumption of certain foods which many people include as a regular portion of their diet. Soy can reduce cholesterol, while tea and wine can also reduce the risk of cardiovascular disease. Cranberries are well known for fighting urinary tract infections, while garlic is considered to be the most widely known herbal remedy (Hasler, 1998).

A list of functional foods is shown in Table 1. This table shows examples of conventional foods and the phytochemicals, antioxidants and omega-3 fatty acids that they contain. It also shows the potential health benefits that can be obtained by consuming these foods regularly in the diet.

The second generation of biotechnology promises to enhance these characteristics in existing foods. For example, the levels of phytochemicals in broccoli and tomatoes can fluctuate substantially. Biotechnology could be used to make the availability of the phytochemicals more consistent. Scientists at Purdue University, in cooperation with the United States Department of Agriculture (USDA), have developed a tomato variety with three times the concentration of lycopene as a conventional variety (BIO, 2004). Another target of the next generation of biotechnology will be to remove the allergens from foods, which commonly cause allergic reactions. Examples are peanuts, soybeans, and wheat.

The most well-known example of a potential functional food developed from biotechnology is beta-carotene enhanced rice, commonly referred to as Golden Rice. Golden Rice has been developed to target nutritional deficiencies in the developing world. Development of Golden Rice has been accomplished through the addition of a daffodil gene so that the rice contains beta-carotene (Lusk, 2003). Regions of the world where rice makes up a large proportion of the diet also have a high level of Vitamin A deficiency. Vitamin A is critical in the health of the eyes and the immune system (Dawe et. al, 2002). However, Golden Rice has not yet become commercially available.

Table 2.1. Foods, Functional Properties, and Health Benefits

Food	Phytochemicals	Antioxidants	Omega-3 Fatty Acids	Potential Health Benefits
Red/Blue Fruit (i.e. strawberries, blueberries)	Anthocyanins			May Slow Aging/Protect Against: Heart Disease/Tumors/ Blood Clots/Fight Inflammation/Allergies
Cruciferous Vegetables	Indoles			Activate agents that may destroy cancer-causing chemicals
Leafy Green Vegetables	Lutein			May Prevent Cataracts/Reduce Risk of Heart Disease and Breast Cancer
Tomatoes	Lycopene			May Reduce Risk of Cancer and Heart Disease
Citrus Fruits/Cereals/Legumes/Oilseeds	Phenolics			May Slow Aging/Protect Against: Heart Disease/Tumors/ Blood Clots/Fight Inflammation/Allergies
Oranges/Green Pepper/Strawberries/Papaya/Red Pepper/Broccoli		Ascorbic Acid (Vit. C)		May Protect Against Various Cancers
Carrots/Squash/Collards/Spinach/Sweet Potato		Beta Carotene (Provit. A)		Enhance White Blood Cells - Block Free Radicals/May Help Decrease the Risk of Certain Cancers
Sunflower/Almonds/Hazelnuts/Peanuts/ Wheat Germ		Vitamin E		Helps Build Red Blood Cells/Antioxidant/May Protect Against Prostate and Colorectal Cancer
Cold Water Fish - Salmon, Halibut, Tuna, Lake Trout / Flaxseed Oil, Beans (Kidney, Great Northern, Navy), Soybeans.			Omega-3 FA	May reduce tumor development in breast and prostate

Source: SCC, 2004

Currently, functional foods are regulated in Canada as regular foods; although future generations of functional foods could have to undergo more intense regulatory scrutiny because of the increased significance of health claims that they could be making. Due to the current regulations, most of the safety assessment is completed through premarket monitoring. The principle of substantial equivalence has been used in Canada and the US to determine food and environmental safety with the products of biotechnology and other novel foods. With the new or increased concentration of phytochemicals in functional foods, the specific differences relative to the closest

conventional comparison would be subject to more intense study (TFILSI, 2004). The regulatory contingencies are further clarified in Section 2.2.

Many consumers have called for postmarket monitoring of GM foods. Postmarket monitoring would specifically follow consumption of the foods and watch for adverse health reactions from consumers that can be directly associated with specific characteristics in foods. An example of a product that has been exposed to postmarket monitoring is the artificial sweetener aspartame. In Canada the studies were performed by the Canadian Health Protection Branch (a division of Health Canada), while in the US the studies were performed by the Food and Drug Administration. The postmarket studies were performed on different segments of the population (i.e. healthy adults, children, lactating females and diabetics) in order to determine their actual consumption rates and the resulting health effects. This was done because regulators felt they could not accurately determine these factors in premarket testing (Butchko et al., 1994). This type of evaluation is also currently used in drugs and medical devices because all situations and reactions cannot be accounted for in premarket testing.

Although the first generation of GM foods have not yet warranted this type of evaluation, the second generation might be forced to complete some postmarket monitoring. The reason is not the fact that the product is GM, but rather that the consumption patterns of these foods will be difficult to estimate in the premarket study. The concern will be the interaction between phytochemicals at increased concentrations in an unknown consumption pattern. This different level of regulation might be forced on the industry, and could be an extra cost that delays the commercial introduction of foods

with new functional characteristics that target specific health problems. However, this is also the type of functional food that will provide the most benefit to the consumer.

2.3 Regulations of nutraceuticals, functional foods and natural health products

The regulation of functional foods can be confusing to industry members, particularly the regulatory differences between countries that complicate international trade. A nutraceutical would fall under the regulations for natural health products in Canada, which are more intensive and well-defined. The majority of the following section on regulations focuses on Canada, but the regulatory situations in the US and the EU is also discussed briefly.

2.3.1 Natural health product and functional food regulation in Canada

The Canada Food and Drug Act was passed in 1953. The Act distinguishes between food and drugs. The distinctions have remained the same since the introduction of the Act. This means that there is currently no provision for a food product to make a claim relating to usage or possible health benefits of the product (Fitzpatrick, 2004a).

On January 1 2004, the regulations for natural health products came into effect. The definition of a natural health product is divided into two parts; these include the function and substance. The function of a natural health product is any product that is manufactured, sold or represented for use in:

- diagnosis, treatment, mitigation or prevention of a disease, disorder or abnormal physical state or its symptoms in humans;
- restoring or correcting organic functions in humans; or

- modifying organic functions in humans, such as modifying those functions in a manner that maintains or promotes health (NHPD, 2003).

The definition of a drug is given in Section 2 of the *Food and Drugs Act*. A drug is defined as any substance or mixture of substances represented, sold or manufactured for use in:

- diagnosis, treatment, mitigation or prevention of a disease, disorder or abnormal physical state or its symptoms in humans or animals;
- restoring, correcting or modifying organic functions in humans or animals; or
- disinfection in premises where food is manufactured, prepared or kept (Food and Drug Act, 2004).

It is interesting to note the similarity between the two definitions; the only difference is the inclusion of animals and disinfection in the definition of drug. However, in the substance portion of the definition for natural health products they are differentiated from a drug. The substance portion of the definition is divided into acceptable and non-acceptable substances. They are listed as follows:

Acceptable Substances:

(a) a plant or plant material, alga, fungus or non-human animal material,

(b) an extract or isolate of the items listed in (a), the primary molecular structure of which is the same as that which it had prior to its extraction or isolation,

(c) a vitamin or any of its salts or derivatives,

(d) an amino acid or any of its salts,

(e) an essential fatty acid,

(f) a synthetic duplicate of (b) through (e),

(g) a mineral; and

(h) a probiotic (NHPD, 2003, pp. 5-8)

Non-Acceptable Substances:

(a) a substance set out in Schedule C of the *Food and Drugs Act*

i) these include radiopharmaceuticals and other drugs for use in the preparation of radiopharmaceuticals

(b) a substance set out in Schedule D of the *Food and Drugs Act*[5], except for

i) a drug prepared from micro-organisms such as an alga, a bacterium or a fungus, and

ii) any substance in Schedule D that is prepared in accordance with the practices of homeopathic pharmacy

(c) a substance regulated under the Tobacco Act

(d) a substance set out in Sections I through V of the *Controlled Drug and Substances Act*[6], and only the following products listed in Section VI are permissible as natural health products:

i) Benzyl methyl ketone

ii) Ephedrine

iii) Ergometrine

[5] For a full listing of the substances listed in Schedule D refer to the *Food and Drugs Act* online at http://laws.justice.gc.ca/en/f-27/61279.html

[6] For a full listing of the substances listed in Schedules I to VI of the *Controlled Drugs and Substances Act* refer to the *Controlled Drugs and Substances Act* online at http://laws.justice.gc.ca/en/c-38.8/text.html

iv) Ergotamine

v) Lysergic acid

vi) Pseudoephedrine

(e) a substance that is administered by puncturing the dermis

(f) an antibiotic prepared from an alga, bacterium or a fungus, or a synthetic duplicate of that antibiotic (NHPD, 2003, pp. 9-10).

The definition of natural health product does not include food anywhere. It will encompass nutraceuticals as defined earlier, but also vitamins and other natural substances in extract form. To date, there have been no instituted regulations for health claims in foods in Canada. Health Canada has put forth a proposed framework for product specific authorization for health claims in foods, but this has not passed the proposal stage (Health Canada, 2001). However, the proposal does lay out the potential applications of the proposed regulations as follows:

- all food and beverages, with or without modification or fortification, that are:
  - in a form readily recognizable to consumers as being food products,
  - consumed to provide nourishment, nutrition or hydration, or satisfy hunger, thirst or a desire for taste, texture or flavour under customary conditions of use or according to instructions, and
  - manufactured, sold or represented to have a direct measurable effect on
    - modifying, restoring or correcting an organic function or body structure of human beings, beyond normal growth and development or maintenance of good health, or

    - reducing the risk of or facilitating the dietary management of diseases or health-related conditions.
- a food or beverage that meets the criteria described above would also be subject to food regulations under the *Food and Drugs Act* and Parts A,B and D (Divisions 1, 2 and 3) of the *Food and Drug Regulations*
- foods meeting the criteria described under the first bullet would be required to carry a Claim Identification Number
- foods meeting the criteria under Division 2 (alcoholic beverages), Division 5 (coffee) or Division 20 (tea) of Part B of the *Food and Drug Regulations* would not be subject to the proposed regulations unless they are sold or represented to have effects described under the first bullet, and
- Parts C and D (Divisions 4 and 5) of the *Food and Drugs Regulations* and requirements governing natural health products would not apply to a food meeting the requirements under the first bullet (Health Canada, 2001, P.6).

Further to the applications of the proposed regulatory framework listed previously, there are conditions underlying the allowable claims that can be made for a food. In general, the food manufacturer or importer must make an application for a Claim Identification Number. In this application, the applicant must include contact information (name, address and telephone number), product information (ingredients, nutrient composition, processing and intended use and target users), and the proposed claim and required information to support it (assessment of product safety, claim validity and quality assurance). The claim validity would be measured through the inclusion of

documentation and studies to support the claim that falls within the appropriate ethical standards and guidelines (Health Canada, 2001).

At the present time in Canada these regulations are not in effect. Functional food manufacturers have had to follow limited allowable claims when labelling functional foods. At the present time there are five allowable generic diet based claims linking a food/nutrient to a reduction in the risk of contracting a disease or condition. An example of the wording of the claims is shown in sub-section 2.3.2. The allowable linkages are as follows:

- Sodium and Hypertension
- Calcium and Osteoporosis
- Saturated and Trans fat, and Cholesterol and Coronary Heart Disease
- Fruits and Vegetables, and Cancer
- Sugar Alcohols and Tooth Decay (Fitzpatrick, 2004a)

In addition, Canadian authorities are considering the addition of five links, which the US has already approved, between certain food/nutrient consumption and the reduction in risk of contracting a disease or condition. These are as follows:

- Folate and neural tube defects
- Fibre-containing grain products, fruits, vegetables and cancers
- Fruits, vegetables and grain products that contain fibre, particularly soluble fibre and risk of coronary heart disease
- Soluble fibre and risk of coronary heart disease (Fitzpatrick, 2004a).

The type of claim that is allowed will be discussed in the section on US regulations below. It should be noted that the lack of concrete regulations for functional

foods in Canada is a concern for industry participants. Fitzpatrick (2004a) states that the ambiguity with respect to functional foods in Canada is the main driver behind the lack of introduction of new products.

2.3.2 Functional food regulations in the United States

Since Canada seems to be following the US in the development of functional food regulations, it is useful to look at the regulatory situation in that country. The US is also a major market for Canadian food exports, so successful introduction of GM functional foods will likely depend on regulatory factors in the US. In the US, health claims on foods that contain omega-3 fatty acids have recently been approved. The type of claim is similar to those listed previously. The claims that are allowed on these types of foods are as follows:

Supportive but not conclusive research shows that consumption of EPA and DHA omega-3 fatty acids may reduce the risk of coronary heart disease. One serving of [name of food] provides [x] grams of EPA and DHA omega-3 fatty acids. [See nutrition information for total fat, saturated fat and cholesterol]. (FDA, 2004, pp.1).

The FDA authorities in the US have been concerned with the estimated 500,000 deaths annually within the US that have been attributed to coronary heart disease (FDA, 2004). They hope that by allowing this type of general claim on products containing omega-3 fatty acids, consumers might include more of these foods in their diets and the incidence of coronary heart disease could eventually be reduced.

The regulations in the US state that in order for a claim to be considered, it must be made in regards to a disease or condition that the US population or a sub-group of the

population (i.e. the elderly) is at risk to contract. In order to verify that the claim is valid, the regulatory authorities will consider the range of publicly available scientific research based on sound experimental design and for which there is significant agreement among the scientific experts in that area (CFR, 2002).

2.3.3 Functional food regulations in the European Union

Another large market for agricultural goods, and one of particular interest because of strict restrictions on GM foods, is the EU. In the EU, health claims must be confirmed through scientific evidence. Where there are health claims included on the label of a food product, the label must also contain some other information. First, the label must contain a statement emphasising the importance of a balanced diet and a healthy lifestyle. If the claim is made referencing disease prevention, a disclaimer must also be made that diseases can have several risk factors, and altering a single factor might have no bearing on reducing the risk of contracting the disease. Second, the quantity of the food that must be consumed to obtain the desired effect must be included on the label. Third, a statement is required listing the type of individuals that should avoid consumption of the product; and fourth, a warning of a quantity (if any) of consumption of the product to avoid because of a risk to health is required (COEC, 2003)

There are also several claims that are not allowed under the EU regulations. There can be no general claims made, such as claims for overall good health or well-being. Claims pertaining to psychological or behavioural characteristics are also not allowed. Weight control and weight loss claims cannot be made on these products. Finally, those claims that make reference to doctor-recommendations, along with claims that state that

an individual's health could be adversely affected if the food was not consumed are not permissible (COEC, 2001).

To simplify the process, the EU has a list of nutritional and health claims that can be made. There is also a list of rejected claims that cannot be made. Some claims might also be restricted, meaning that they cannot be used without first going through the proper authorisation process (COEC, 2001). Through this registry, firms involved in researching new foods have a clear guideline to the requirements they must meet in order to make claims. Also, these firms can find out what degree of testing and authorisation they must have to make the claims.

From the overview of the regulations in Canada, the US and the EU it is evident that although Canada is moving to more well-defined regulations for natural health products, it is falling behind in regulations for functional foods. It is important that governments regulate, not only to provide guidance to innovators, but also to provide standards that help to protect the safety of consumers. Without proper regulation with respect to claims, there is the potential for the problem of information asymmetry because consumers might not know what health benefits or concerns arise from consuming certain foods.

The focus of this project is to examine the set back to the introduction of GM functional foods. One possible explanation is the regulatory uncertainty that exists in Canada with respect to these products. The next section examines the literature with respect to consumers, biotechnology and functional foods. It also examines the food manufacturer's decision to expand their brand, which may have more influence on the potential set back to commercialization than individual consumer aversion.

2.4 Consumers and biotechnology

Since the introduction of GM crops in 1996, farmers in Canada and the US have rapidly adopted the technology. In response to the rapid introduction of GM crops into the food chain, some consumers have voiced their opposition to the farming and production of GM foods (Klein et al., 1998). This has been especially prevalent in the EU, where lobby groups have a strong voice. Much of the aversion to GM foods has been emphasised by non-governmental organisations (NGOs), which include this opposition with a wider focus on reducing globalisation and free trade (Klein et al., 1998). Hobbs and Plunkett (1999) stated that a key driver for these concerns is that consumers have a lack of accurate knowledge about, and a lack of confidence in, the science and regulation of GM foods. A history of food-related problems such as Bovine Spongiform Encephalopathy has reduced the public trust of Europeans towards food manufacturers and regulators. Finally, to this point, the benefits of GM crops have for the most part been enjoyed by the developers and farmers (agronomic benefits). Consumers have not received a direct benefit in return for what some perceive as an increased risk. Regardless of whether there are any true long term health effects from consuming the products of biotechnology, the high level of consumer aversion creates concern for regulators, lifescience firms and food manufacturers. This section reviews literature regarding consumer concerns and the factors affecting willingness-to-pay to avoid existing GM foods, or to consume hypothetical GM foods with functional output traits.

Some consumers have ethical concerns regarding the GM technology (Hobbs and Plunkett, 1999). These consumers are not concerned with the food or environmental

safety of the GM food; rather they are concerned that the processes used to create the technology are unethical. This group of consumers create a concern for the developers of GM functional foods because further proof of safety and efficacy of the functional foods will have little effect on their purchase decision. This is because this portion of the population is more concerned with the process in which the good is produced, not the benefits received from the end product (Frewer et al., 1997). The only way these consumers are going to change their opinion is to learn some new information that changes their ethical opposition.

Studies on the welfare effects of GMOs have concluded that if the benefit of the first generation of GM crops is not passed on to the consumer through a price low enough to compensate for the aversion to the technology, there may be net welfare loss to society (Fulton and Giannakas, 2004; Plunkett and Gaisford, 2000). However, for the second generation of functional foods, some consumers could receive an additional health benefit from the technology. This could possibly outweigh the negative effects on utility from aversion to the GM component of the technology.

In many cases, the consumer aversion to GM foods could be overestimated by consumer studies. In an International Food Information Council survey using American consumers in 2003, respondents were given an open-ended question regarding whether they would like additional information on food labels. The results showed that 77% of respondents could not identify any additional label information that was not currently present. Respondents who did identify additional information mostly wanted increased nutritional information (9%). In this survey, only 2% of American consumers listed labelling of GM foods as a priority (IFIC, 2003).

There has been increasing demand for organic foods, which are non-GM by definition (AMS, 2005). In Canada, organic consumption has been growing at 20-25% annually, with retail sales of $0.75 to US $1 billion in 2003 (Kortbech-Olesen, 2004). The US is the world's largest market for organic food with sales estimated at US $8 billion in 2000 (Kortbech-Olesen, 2002), with growth expected at a rate of 20% annually (Greene et al., 2001). The EU market was US $4.5 billion in 1998 (Wier and Calverley, 2002). However, in all cases, the consumption of organic foods still only comprises 1-2% of total food purchases (Kortbech-Olesen, 2002).

A potential reason for less dramatic growth in consumption of non-GM food in North America compared to Europe is that North American consumers might not realize the prevalence of GM crops in the foods they eat. One would expect that even if a small percentage of consumers who claim to be concerned about GM foods purchased organics, the market share of organic foods would be larger. A possible explanation is that consumers do not express their concern in the retail market as strongly as it is captured in consumer studies (Smyth and Phillips, 2003). Another explanation is that consumption of organic foods can only increase at the same rate as supply. In the US, the consumption and supply of organic foods seem to be increasing at the same rate (Greene et al., 2001). However, the link between concern for GM foods and an increase in non-GM and organic food has not been proven. There are several explanations for the increase in demand for organic food including environmental concerns, desire that food be chemical-free, perceived enhanced animal welfare and apprehension about GM technology (Greene et al., 2003).

There have been numerous attitudinal surveys performed on potential consumers to determine their attitudes towards GM foods. Hypothetical stated preference studies can overestimate the aversion that consumers have to GM foods. Marks et al. (2003) state that although hypothetical consumer preference studies by Hallman (1996) showed that consumers in the US had a strong aversion to GM milk, the percentage of consumers purchasing rBST-free milk is very small.

Even more surprising is a separate revealed preference study on Dutch consumers at the retail level. Marks et al. (2004) initially predicted that given strong opposition to the introduction of GM foods into the European market it would follow that given a choice, most Europeans would consume non-GM foods. The data set was collected from April 13 1997 until December 30 2001. GM labels were added on June 22 1997 and removed May 14 2000. The empirical work was completed using an AIDS model. The goods either contained GM ingredients and carried a GM label, or contained no GM ingredients and carried no label. The products were positioned beside each other on the retail shelves. The effects of own price, substitutes' prices, per capita real expenditure for the product category, holiday effects and the addition and removal of GM labels were accounted for in a non-linear conditional expenditure model. Also, the effects of media coverage were included (Marks et al., 2004). Using canned soup, frozen processed meat, frozen pizza and frozen processed fish to follow consumption patterns it was concluded that adding a "contains GM ingredients" positive label did not significantly alter the purchasing behaviour (Marks et al., 2004).

The interesting question then becomes whether consumers are willing to pay for functional characteristics in foods that are attained through biotechnology. Lusk (2003)

uses contingent valuation to determine the willingness to pay for Golden rice among respondents in the US state of Mississippi through a mail survey sent out in July 2001. A concern that exists with contingent valuation is the hypothetical bias that could cause respondents to overstate the amount that they are willing to pay. Lusk (2003) tries to limit the hypothetical bias by using a technique referred to as 'cheap talk'[7]. 'Cheap talk' is additional information that is provided to the consumer to make them better informed in order to limit the hypothetical bias. It was found that consumers not given 'cheap talk' exhibited more inelastic demand than those who received it (Lusk, 2003). Those given 'cheap talk' were willing to pay US $0.13 less than those who did not receive it. However, 'cheap talk' did not completely eliminate the hypothetical bias. If the price of conventional white rice was US $0.70 per pound, those not given 'cheap talk' were willing to pay US $1.00 per pound for Golden Rice, while those who received 'cheap talk were willing to pay US $0.87 per pound (Lusk, 2003). This wide range of responses would be a concern to someone attempting to perform profitability estimates (Lusk, 2003).

There are several factors that consumers take into consideration when making the decision to purchase, in addition to whether the food contains GM ingredients. Lusk et al. (2002) used a form of conjoint analysis called a choice experiment to determine consumer willingness to pay for corn chips. The sample was composed of students enrolled in an agricultural economics course at Kansas State University. The students were given a series of questions where they gave demographic information and were

[7] Lusk (2003) performs 'cheap talk' by employing a 'cheap talk script'. The 'cheap talk script' explains the fact that in past surveys similar to the one the respondent is about to complete, the respondents showed hypothetical bias. It stated, "…80% of people said they would buy the new food. However, when a grocery store actually put the *same* new food on their shelf, *but* where payment was real and people *really* did have to pay money if they decided to purchase the new food, the results were that only 43% of people *actually* bought the new food." (Lusk, 2003, pp.856)

surveyed regarding their preferences regarding GM foods. The main experimental procedure followed the survey. Both first and second-price auction formats were used to randomly determine bids on different bundles of characteristics. This method gives respondents a choice of bundles of goods with different attributes, in a number of combinations in order to generate a willingness to pay for certain attributes. In this study, consumers chose between brands (Tostitos and No Brand), stores (Kroger and Jitney Jungle), price ($4.00, $3.00 and $2.00), and type of corn used (GM corn to increase yield, GM corn to increase shelf life and non-GM corn).

The analysis showed that the brand had a much larger effect on willingness to pay than all other factors combined. Consumers were willing to pay US $1.70 more for a bag of Tostitos than No Brand. The willingness to pay for corn chips purchased at Kroger was US $0.65 more than those purchased at Jitney Jungle. Consumers were willing to pay US $0.33 more for GM corn chips with increased shelf life compared to GM corn chips that gave higher yield. However, when compared to non-GM corn chips, consumers were only willing to pay US $0.01 premium for GM corn chips that increased shelf life. Lusk et al. (2002) conclude that brand image and store loyalty has a much larger impact on consumer choice than the type of corn used to produce the chips.

Larue et al. (2004) specifically attempted to identify the willingness to pay for GM functional foods. In April 2001, a telephone survey was performed by SOM Inc. to gather data from a representative sample of 1008 Canadian respondents. In a stated-choice experiment, respondents chose from descriptions of hypothetical foods produced through conventional, organic and GM methods. The available products were tomato sauce, potato chips and chicken breasts. The tomato sauce had a functional property of

"anti-cancer", while chicken breasts and potato chips had a "heart-healthy" functional property. A random parameters logit model was used to generate the results from the survey. The results showed that the utility of the respondents increased from potato chips that contained the "heart healthy" label, regardless of whether the potato chips were produced through conventional or GM methods. The mean coefficients for chicken breasts and tomato sauce with functional properties created through GM techniques were not significantly different from zero, while the corresponding standard deviation coefficients are significant (Larue et al., 2004). They stated that this implies that for about half of the consumers the utility from the functional property induced through GM was larger than that through conventional means, and for the other half of consumers it was smaller. Larue et al. (2004) then estimated the willingness to pay for the functional properties for conventional and organic functional foods. None of the GM goods have statistically significant results.

The value of the functional property in chicken breasts was CDN $1.88/kg for conventional and CDN $8.25/kg in organic, while it is only CDN $0.73/kg for GM. For potato chips, the value of the functional properties are CDN $0.64/150 gram bag of conventional, CDN $1.16/150 gram bag of organic and CDN $0.85/150 gram bag of GM. Tomato sauce with functional properties had estimated premiums of CDN $0.64/398 ml can for conventional, CDN $0.50/398 ml can of organic and CDN $0.73/398 ml can of GM.[8] It is interesting in this case that the GM tomato sauce commands the highest premium, especially since it has the lowest average price. However, the high standard deviations in both the conventional and GM estimates means that the two premiums are

[8] These premiums were calculated relative to average prices. The average prices for organic were estimated at approximately twice that of conventional, while the average prices for GM were estimated somewhat below the conventional price.

not statistically different. This was a surprising result that consumers might pay the same premium for functional health properties in GM and conventional foods. However, the remainder of the results led Larue et al. (2004) to conclude that the majority of consumers prefer conventionally produced goods over organic or GM, even though there were smaller groups of consumers with preferences for organic and GM produced foods. The final conclusion is that the introduction of functional traits in GM foods might make them more popular, as long as similar traits are not available in conventional or organic foods.

Consumer preference and willingness-to-pay studies give an indication of the general views of consumers towards biotechnology, and the potential values they place on functional characteristics. However, it must be understood that there are limitations to the accuracy of these studies. Consumers do not hold a static set of preferences towards food. Media coverage and scientific studies can influence individuals' preferences. The research and development process involved in producing GM functional foods can be expected to take more than 10 years. Innovators within the industry likely need to base decision-making on more than hypothetical studies based on individuals' preferences that could change (Stark, 2005).

Consumers' aversion to GM foods is definitely important to food manufacturers who are considering which ingredients to use in their products. The introduction of GM functional foods will create an additional issue for food manufacturers. The effect of the brand image of a firm may be an important factor for a food manufacturer in deciding whether to introduce a GM functional food to its product line. The following subsection reviews literature with respect to branding.

2.4.1 Consumers and branding

Consumer preferences for a specific product are not the only factor that a firm is likely to take into consideration when making the decision to add a new product. Many firms in the food processing industry produce a line of diverse products. The decision to expand the brand to include a GM functional food is more complex than simply determining whether there is a group of consumers willing to pay a premium for the product. Even if the product itself finds a niche and is profitable, there might be backlash against the whole brand by consumers who have strong preferences regarding GM foods. The following section deals with the firm's decision to expand their brand.

The decision to stretch a firm's brand to new products can have broad effects on the firm as a whole. Cabral (2000) discusses three effects of stretching a brand. The first is the *direct reputation effect*, whereby the firm's reputation influences the willingness to pay for a new product. The *feedback reputation effect* is the change in the willingness to pay for the original product as a result of the performance of the new product. Thirdly, the *signalling effect* is a signal of overall firm quality that represents the overall effect of stretching the brand on both old and new products. Overall, Cabral (2000) makes several propositions according to the effects explained above. For any given reputation, the firm with the highest quality is most likely to expand. For any given quality level, the firm with the highest reputation is most likely to expand. If the new product provides a high level of profit compared to the base product, firms with a sufficiently high reputation will stretch their brand to take advantage of their reputation. Finally, if the new product is relatively unimportant in terms of profitability, firms with a low reputation expand in an

attempt to boost their brand. On a similar product, a firm with a high reputation is unlikely to expand because of the desire to protect their image.

Empirically, Jarrell and Peltzman (1985) showed that in automobiles and drugs, the cost of bad news on one product can have a negative impact on the firm as a whole. The study divided the cost of drug and automobile recalls into direct and capital market costs. The direct costs were the actual costs involved in recalling the products, combined with the costs incurred to try to gain back consumer confidence. The capital market costs were the losses to the firms in terms of share value resulting from the recall. The study period ran from 1974 to 1982 for drug recalls and 1967 to 1981 for automobile recalls. The effect of a one dollar increase in the direct cost of a drug recall was an increase of two to four dollars in the shareholders' loss for that firm. The study was unable to draw an equivalent link in the automobile case because individual recall costs were not recorded. It was concluded that in both cases the wealth of the shareholders was more negatively affected than the direct cost to the firm. This resulted from a general loss to the goodwill value of the firm. Also interesting was the conclusion that in both cases, the shareholder value of the firm's competitors also declines. Any potential benefit from the increased demand for substitutes is outweighed by negative perceptions of the industry in general (Jarrell and Peltzman, 1985).

In the context of GM functional foods, a product with tangible and valuable health benefits would be similar to high quality. Given that the GM functional food had a high quality, the strongest brand would be most likely to expand. If the benefits from the GM functional food were less tangible, it could be considered "unimportant". A firm with a low reputation would be more likely to expand their brand in this case.

If one assumes that, at least for the initial GM functional foods, the health benefits will be relatively small, firms with lower reputation could be responsible for their commercialization. In food markets, one could divide the market into national brands (i.e. Kraft, Heinz), private labels (i.e. Safeway Select, Our Compliments – Sobeys) and discount private labels (i.e. Smart Choice – Sobeys, No Name – Real Canadian Superstore). Of these choices, the private labels are growing in popularity. In the United Kingdom, 62% of new product launches come from own-brands (Henson and Northen, 1998). It is difficult to make a hypothesis regarding who could expand their brand to include GM functional foods. The concentration of food manufacturers and retailers means that most firms involved have a reputation to protect. National brands generally have a large and diverse product offering. Private labels, while sometimes selling at a discount, do not necessarily carry a lower reputation. The expansion of a private label can effect the reputation of the store (i.e. Safeway, Sobeys) as a whole.

Potential consumer aversion to GM foods is a major concern to those firms putting resources into developing functional foods from biotechnology. Not only is this a concern to the lifescience firms developing the primary crops, but also to the food manufacturers. This could be an important component of the set back to commercialization of GM functional foods. Perhaps food manufacturers and lifescience firms are waiting for the vocal opposition from consumer groups and NGOs to recede before investing substantial resources into product development.

Food manufacturers, especially those with valuable brand identities, are reluctant to introduce new food products that have the potential to be controversial (Fitzpatrick, 2004b). Any new food safety or consumer satisfaction problem could negatively affect

the entire brand image. If this is combined with the criteria under which a firm decides to expand its brand discussed by Cabral (2000), there might be only a small number of firms interested in investing in GM functional foods. In combination with the problems described in the following sections, there is convincing reason to predict that several issues are causing a delay in the commercialization of GM functional foods.

The problem of consumer aversion, and the issues that accompany it, become even more important when the extra costs required to gain access to patented intellectual property are considered. The relative complexity of the intellectual property involved in the creation of GM functional food creates additional costs for the seed developer, which will have to be recovered through the supply chain, possibly in part through a higher consumer price. The following section outlines the issues created through the requirements firms have to gain access to intellectual property.

2.5 Access to intellectual property

The second generation of GM foods will face a unique problem that has until recently, not been a major concern to the food industry. Since the landmark case in the US of *Diamond v. Chakrabarty* in 1980, biotechnology, seed and agrochemical firms have started intensive research efforts (Graff et al., 2003). The case resulted from a patent application filed by Chakrabarty in 1972 for genetically engineered bacteria that was to be used in cleaning up oil spills. Chakrabarty was employed by General Electric Company at the time. Chakrabarty made three types of patent claims: the first was a method to produce the bacteria, the second was a carrier for the bacteria (i.e. straw), and the third was the bacteria itself (FLLP, 1980). Initially, the first two were accepted by the

US patent office, but the third was rejected with the reason being that micro-organisms are products of nature. This decision was appealed and overturned with the ruling stating that the fact that the micro-organisms were living did not have legal significance (FLLP, 1980). Once a firm or individual receives the patent rights to a product/process such as in the Chakrabarty case, it follows that the innovator has sole access to the returns from their innovation (Smith, 2002).

A patent holder can share its sole access to a product through negotiating licenses with other firms and individuals. Licensing has drawbacks, because of transaction costs, including information and negotiation costs. Williamson (1986) posits that costs that occur in commercial activity are the economic equivalent of friction in physics; if they are denied consideration, the results become inaccurate. Information and negotiation costs are two of three classifications of transaction costs, the third being monitoring and enforcement costs. Information costs occur *ex ante* to the transaction and include all costs of identifying the negotiating partner and gaining price and product information (Hobbs, 1997). The process of gaining access to the intellectual property necessary to develop GM functional foods could be a major cost. All the processes could potentially be patented by different firms. The interested firm must identify what has been patented, and by whom, before any negotiation occurs. This can prove to be the most difficult process (Devine, 2004). Following the information gathering stage, the firms must negotiate a license for use of the patented product or process. Negotiation costs include the costs of actually performing the transaction. Included are the commission costs, the costs of negotiating the terms of the contract and actually preparing the contract (Hobbs, 1997). Often it is understood by both parties that, due to the length of the negotiation period to

gain patent licenses, research will continue during this period. This ongoing research time is included in the license agreement (Devine, 2004).

In several cases in the lifescience industries, firms have avoided these costs through mergers and acquisitions. Hubbard (1997) explains this behaviour as an outcome of inadequate institutions, such that the industry will exhibit low barriers to entry accompanied with a high barrier to growth. In the case of intellectual property, the lack of a structured market to facilitate the exchange of licenses could be considered an inadequate institution. Although patents are recorded in national databases world-wide, the process of searching for whether a piece of technology is the intellectual property of another individual/firm takes time and resources. This potential inadequate institution could be considered a possible explanation for the present structure of the agricultural biotechnology industry.[9]

An explanation of the current industrial structure of the lifescience industry is given by Fulton and Giannakas (2001). The paper lists sunk costs of intellectual property and research and development, combined with the sunk costs of gaining regulatory approval as the first reason for increased concentration in the lifescience industry. The second reason is the escalation strategy, consisting of mergers and acquisitions by firms in the industry in an attempt to gain a dominant position. The changes in vertical structure of the lifescience industry are explained in two ways. First, some products have been designed so that they are complements to certain pesticides. In these cases it is most

[9] It could be argued that there are high barriers to entry in the agricultural biotechnology industry, but there have been examples of relatively small companies which have developed significant intellectual property. The former agricultural biotechnology firm Calgene started small but developed the genetic technology to delay ripening in tomatoes (Flavr Savr), resistance to the herbicide bromoxynil in cotton and industrial oils in canola. Calgene showed promise, but could not succeed under the economic pressures caused by the commercial introduction of the Flavr Savr tomato along with other issues, and was purchased by Monsanto Corporation on April 1 1997. In the first quarter of 1997, Calgene had reported its first profit since it started to expand its operation ten years earlier (Martineau, 2001).

profitable if the pesticide and seed are marketed by the same firm so that the proper incentives can be used to maximize joint profits.[10] Other GM crops are substitutes for pesticides, which does not encourage mergers and acquisitions because the increase in demand for one decreases the demand for the other.[11] The intellectual property involved in a vertical market might also play a role in the vertical structure of the industry. Firms might vertically integrate to avoid opportunistic behaviour by the firm who holds the intellectual property rights. They might also become more closely vertically coordinated because the use of the intellectual property requires more than just a transfer of knowledge (Fulton and Giannakas, 2001).[12]

The market share that individual firms hold in the market for seeds representative reflects the market concentration. The corn and soybean seed markets give a good indication of this concentration. DuPont and Monsanto have become two main competitors in this industry. Through its ownership of Pioneer Hi-bred International, DuPont held a 40% market share in corn seed and a 16% market share of the soybean seed markets in 1998 (Kalaitzandonakes and Hayenga, 2000). Monsanto, through acquisitions of former competitors Asgrow and DeKalb, held a 15% market share in the corn seed market and a 24% market share in the soybean seed market (Kalaitzandonakes and Hayenga, 2000). When combined with the control Monsanto has over germ plasm[13],

[10] For example, the herbicide Liberty, and LibertyLink and InVigor Canola Produced by Bayer CropScience.
[11] For example, Bt crops (i.e. potato) and the pesticide used to control damaging insects (i.e. Imicloprid).
[12] Fulton and Giannakas (2001) argue that the intangible assets such as the timing and other specifics involved in the steps of biotechnology are examples of the difficulty in licensing. This is overcome by including transformation services in the terms of the agreement.
[13] Charles (2001) explains that it is not only the intellectual property in genetics that influence the value of a new seed for a crop. The owner of the germ plasm also holds a lot of power because of the years of selective breeding that have gone into developing it.

the two companies combined to hold full ownership or influence over 80% of the corn seed market in the US in 1998 (Kalaitzandonakes and Hayenga, 2000).

With growth in the size and concentration of firms in the agricultural biotech industry comes concern over the market power that these firms possess. Brennan et al. (2000) estimated the four firm concentration ratio of firms developing plant biotechnology by studying US field trial data. The four firm concentration ratio increased from 64% in 1993 to 79% in 1998, mainly as a result of merger activity (Brennan et al., 2000). This is a cause for concern for primary agricultural producers who are affected by the prices of inputs, including seed and pesticides. Also, all agricultural biotech firms interested in acquiring licenses to use the patent also will be affected by the market power of the firms holding the patents. To put the market power into perspective, Graff et al. (2003) show that Monsanto has 14% of all agbiotech patents in the US, followed by DuPont (13%), Syngenta (7%), Bayer (4%) and Dow (3%). These five firms hold a total of 41% of all agbiotech patents. The remainder of the private firms have 33%, while public institutions hold 24% (Graff et al., 2003).

Although the previous point examines the potential complications in the US because of market concentration, the situation is complicated further by the fact that patent regulations and intellectual property rights differ substantially at an international level. In the case of functional foods derived from biotechnology, there could be multiple transgenes involving several patents from different countries (Kowalski et al., 2002). This complicated scenario could result in a multitude of negotiations for licenses, leading to potential innovations becoming infeasible.

Currently, licenses are negotiated bilaterally between the firm doing research on a new product or process and the owner of the intellectual property. There are limited standards in place and the negotiations are conducted on a case-by-case basis, which consumes time and resources. A possible solution to the inefficient manner in which licenses are currently negotiated is an independent clearinghouse for patents. Perhaps as a result of realizing the market power that they have with respect to patents, license holders have begun to market licenses rather than hold sole user status (Graff and Zilberman, 2001). By facilitating the trading of licenses through a clearinghouse, several transaction costs could be reduced. First of all the information costs are reduced, because information concerning patented products/processes and the firms holding them would be well organized and easily accessible. Second, negotiation costs would be reduced because the clearinghouse would provide the institution necessary for the market to function.

Graff and Zilberman (2001) identify three purposes of the IP clearinghouse: first, to identify the patents over technology available for licensing; second, to match buyers and sellers with standard yet flexible prices and contract terms; and third, to monitor and enforce the contracts. In order to maintain trust and ensure no conflicts of interest, a neutral party would be used to operate the IP clearinghouse (Graff and Zilberman, 2001). The closest instrument available at the present time is the Public Intellectual Property Resource for Agriculture (PIPRA). PIPRA offers public institutions the opportunity to submit copies of their patents and the status of licenses to be included in a database accessible to other researchers (PIPRA, 2005). It is not a clearinghouse, but this database could be the first prototype for a future clearinghouse. Presently this type of market does not exist for patents for private firms, meaning that new entrants attempting to develop

agricultural biotech innovations face information, market power, and limited resources problems. The result is a potential hold up for innovations in GM functional foods. Even if firms develop new technologies, the costs to obtaining the licenses to commercialize the product could be prohibitive.

Functional foods produced from biotechnology may require access to multiple patents held by numerous firms. The best known case in Golden Rice, where for any single country it could be introduced in there is up to more than 40 patents applying to the product. Across different countries, there are more than 70 patents (Kryder et al., 2000). This could easily be one of the main factors delaying the commercialization of Golden Rice.

In the case of Golden Rice, Monsanto made the decision to share its proprietary information (Falcon and Fowler, 2002). Falcon and Fowler (2002) state that this decision followed a pledge by Novartis to provide seed technology to subsistence farmers at no charge. However, these are examples of products designed for markets in third world countries where there are no large rents to be distributed. The set back to commercialization of GM functional foods destined for markets in developed countries still remains because presumably the market for these products would create rents for the parties to bargain over.

The next generation of GM research is focusing on more lucrative consumer markets in developed countries. For example, Monsanto is currently in the early development phase of producing soybeans with no saturated fat (Fraley, 2005). Firms holding patents to the genetic material needed to develop these functional foods will want to have access to rents that accrue from the development of these new technologies.

Therefore, there is the possibility that patent-holders could command a price for licenses which is too high to allow for a return to the potential licensee, meaning the research will not continue and commercialization will be held-up. This extreme example is unlikely given that the possible returns to the patent-holder from licensing could exceed the returns from maintaining exclusive access. Exclusive access to the intellectual property holds a lower value relative to the returns from licensing, in many cases because the owner of the intellectual property lacks the specialized knowledge held by the firm seeking the license (Bessen, 2004). The exception would be a firm that was developing a competitive or substitute product. Many licenses are required for processes involved in biotechnology that in no way are part of the traits shown by the final product. Bessen (2004) states that as long as the expected returns from gaining a license exceed the difference between the cost of research and development and the license cost, firms will obtain a license for the technology. It is also important to consider that often the initial innovators are solely researchers and have no intention to commercialize the product on their own. These firms rely on the income generated from licenses to cover the costs of research (Scotchmer, 2004).

Overall, the set back caused by the transaction and licensing costs involved with gaining access to intellectual property is another potential cause of lack of commercialization of the functional foods derived from biotechnology. It is just one of several explanatory factors that should be considered.

2.5.1 The supply chain effects of access to intellectual property issues

The fact that firms involved in developing the second generation of GM foods will likely have to make investments in IP licenses will cause reverberations throughout the supply chain. Transaction cost economics can be used as a framework to analyse the potential supply chain of GM functional foods in order to make inferences later in this thesis.

The stylized supply chain for GM functional foods will likely be comprised of several levels. The supply chain could begin simply with the owner of knowledge or intellectual property. This intellectual property could be licensed to the agricultural biotech firm that will develop the seed. The agricultural biotech firm could then market the seed to producers who grow the seed and market it to processors. Within these last two stages the producer will be working through an agent, in most cases a crop inputs dealer and a grain buyer. The processor will then sell the finished processed goods to a wholesaler/retailer. At each one of these steps, the parties involved in the transaction would likely be involved in some type of contract.

Williamson (1986) states that the conjunction of bounded rationality, opportunism and asset specificity is the basis for transaction costs. In the absence of any of these three factors a much simpler contract emerges (Williamson, 1986). Williamson (1986) describes the three factors as follows: bounded rationality when individuals are "*intendedly* rational but only *limitedly* so" (Simon, 1961, p.xxiv, cited in Williamson, 1986), opportunism as "self-interest seeking with guile" (Williamson, 1986, p. 177), and asset specificity, which is investment in an asset that holds little or no value in an alternate use or to an alternative user. These factors are likely to affect the supply chain for GM functional foods.

When compared to conventional agricultural crops, firms involved in the supply chain for GM functional foods will have to make relatively more specific investments. For instance, if licenses are purchased as a flat fee, that fee is a type of sunk cost. If the product is not commercialized that license will be worthless. The degree of asset specificity that the agricultural biotech firm faces by investing in the technology to develop a food depends on the degree to which the food is developed for a specific processor/retailer. Klein et al. (1978) state that when the degree of asset specificity increases, the amount of quasi-rents available increase simultaneously. As the quasi-rents increase the temptation for opportunistic behaviour increases, which will likely lead to vertical integration as the cost of contracting increases. In the area of agricultural biotechnology, and particularly with the production of GM functional foods, bounded rationality is an important issue to all parties involved. The lifescience firm must decide at least 10 years ahead of commercial introduction what type of health characteristic the consumer will demand. Consumer tastes are likely to change in that period of time as a result of alternative products and increased information. Also both sides have bounded rationality with regards to an unforeseen issue with the food following the commercial introduction. This leads to uncertainty at the onset of development and throughout the lifespan of potential GM functional foods.

Further complicating the possible supply chain for GM functional foods is the fact that market concentration exists in the lifescience and food manufacturing industries. There is a small numbers bargaining problem. Presumably as a result of a patent on the functional seed, the agricultural biotech firm will have a monopoly. The food manufacturer might also negotiate a contract where they gain exclusive access to the

technology for food production, giving them a monopsony. In situations of bilateral monopoly, Williamson (1971) states that both price and quantity are negotiable. A stylized depiction of this situation is shown in the next chapter in Figure 3.1. In theory, the firms can maximize total profits by operating on the contract curve but in practice the parties will bargain over distribution of the rents which could lead to a sub-optimal solution. In this case any price that leads to non-negative rents for each party will be feasible (Williamson, 1971). The final outcome will depend on the relative bargaining power of the negotiating firms. When one considers the fact that there are bilateral monopoly negotiations possible between the patent-holder and agricultural biotech firm for licenses, and in turn the agricultural biotech firm, and the food manufacturer, the number of possible rent distribution scenarios becomes exhaustive. Williamson (1971) states that the transaction cost implications are that firms would be expected to vertically integrate in cases where the bargaining costs become high enough that the two firms would be better off working as one. The level of vertical coordination would also become higher as the level of trust declines (Williamson, 1971). This situation is further complicated if access to intellectual property must be negotiated with two or more intellectual property owners.

In today's marketplace, firms commonly form strategic alliances between one another as a less drastic option to complete integration. The form of strategic alliance ranges from a license to an equity joint venture, which is referred to as least hierarchical and most hierarchical respectively by Oxley (1997). This is a possible outcome for the supply chain of the next generation of biotech products. Oxley (1997) gives several hierarchical outcomes for strategic alliances depending on several characteristics of the

transaction. The paper makes five observations predicting likely hierarchical structures given transaction characteristics. The observations state that a more hierarchical structure will be formed if: (1) the alliance involved a product or process design as compared to a marketing or production alliance, (2) there are a broad range of products or technologies, (3) the transactions take place over a wide geographic area, and (4) the parties are involved in few rather than many alliances together (Oxley, 1997). Following the logic of this paper, the supply chain for GM functional foods could possibly have several hierarchical levels depending on the specific product being produced and the parties involved.

This section shows that the transaction cost effects resulting from the need to gain freedom to operate, along with the fact that there is monopoly power at either end of the supply chain leads to a complex set of supply chain interactions.

2.6 Summary

This chapter begins by giving a background to the issue, including definitions and the regulatory environment for functional foods in Canada, the US and the EU. The regulatory environment, especially in Canada is uncertain. Health claims for functional foods are currently being approved on an ad hoc basis and the remainder of the sector remains in regulatory limbo. This does not give innovators a clear idea of what type of regulation will exist in ten years time when ideas currently under development become ready for commercialization. This regulatory uncertainty is one potential contributor to the set back to commercialization of the next generation of GM products.

The consumer literature pertaining to GM foods shows that there is aversion to GM foods. When given the choice, most consumers would opt for conventionally produced foods over a similar GM food. However, there is some evidence of willingness to pay for GM foods that provide consumers with health benefits. The issue then becomes whether it is worth the risk for a food manufacturer to invest in developing new foods that might reflect negatively on their brand as a whole. Consumer perception of a product can change rapidly as a result of unforeseen negative news regarding an issue such as food safety. A recall of a GM functional food could damage the value of the firm and brand as a whole. These factors add to the uncertainty involved in investing in GM functional foods, lending another reason for potential delay in commercialization.

Finally, the literature relating to the issue of freedom to operate and the effects on the supply chain as a whole is discussed. The result of the necessity to gain access to intellectual property is increased transaction costs to the supply chain as a whole. There is a lack of an institution to facilitate the exchange of information regarding IP, including terms of exchange and a basis for pricing. In the case of development of GM functional foods, numerous pieces of intellectual property may have to be licensed. As a result of the institutional shortcomings and the number of licenses required, there will be large transaction costs involved in obtaining the licenses necessary to proceed with further development of GM functional foods. This combined with the fact that there are rents to be distributed by bilateral monopolies at multiple levels of the supply chain, means that the contract negotiation becomes extremely complex. The combination of factors will not only lead to higher transaction costs, but also the multiple levels of bilateral monopoly will lead to a potential hold-up problem because of the difficulty in distributing rent.

This chapter provides evidence from existing literature highlighting the conditions with the potential to cause a set back to the commercialization of GM functional foods. The literature and background in this chapter are the basis of deeper analysis presented in subsequent chapters. The next chapter presents a theoretical analysis of these issues.

CHAPTER THREE

THE THEORETICAL MODEL

3.1 Examining the vertical market

When analysing the possibility for a set back in the commercialization of GM functional foods, it is helpful to conceptualize the situation as a vertical market. From the model of the vertical market, the potential problems can be analysed, and circumstances where there is expected to be success or failure can be explained. The following sections analyse and model the three problems that contribute to the delay to commercialization of GM functional foods: regulatory uncertainty, the set back at the food manufacturing level resulting from the risk to the brand image exceeding the benefit gained from consumer demand, and costs associated with gaining the access to intellectual property.

As indicated at the end of the previous chapter, the supply chain in the GM functional food market can be visualized as several levels. To simplify the analysis, the three levels shown in Figure 3.1 will be used. The furthest upstream firm is the lifescience firm, followed by the primary producer of the crop and the food manufacturer.

In conventional farming, the producer purchases seed from the lifescience firm and sells to the food manufacturer either through a contract or in a spot market transaction. The producer, being perfectly competitive, gains zero economic profits. Assuming the producer receives a premium to grow the GM functional food crop, but

also pays a premium in seed and management costs, the net economic gain for producers to grow GM functional food will be assumed to be zero. For this reason, it is assumed that the producer has no market power. As a result, the main focus of the theoretical chapter is on the lifescience firm and the food manufacturer. It is assumed that the producer enters into a resource-providing production contract with the food manufacturer. This means the food manufacturer provides the seed to the producer, who grows the crop in an agreed upon method for the manufacturer. The manufacturer will negotiate a contract with the lifescience firm that allows them exclusive access to the technology.

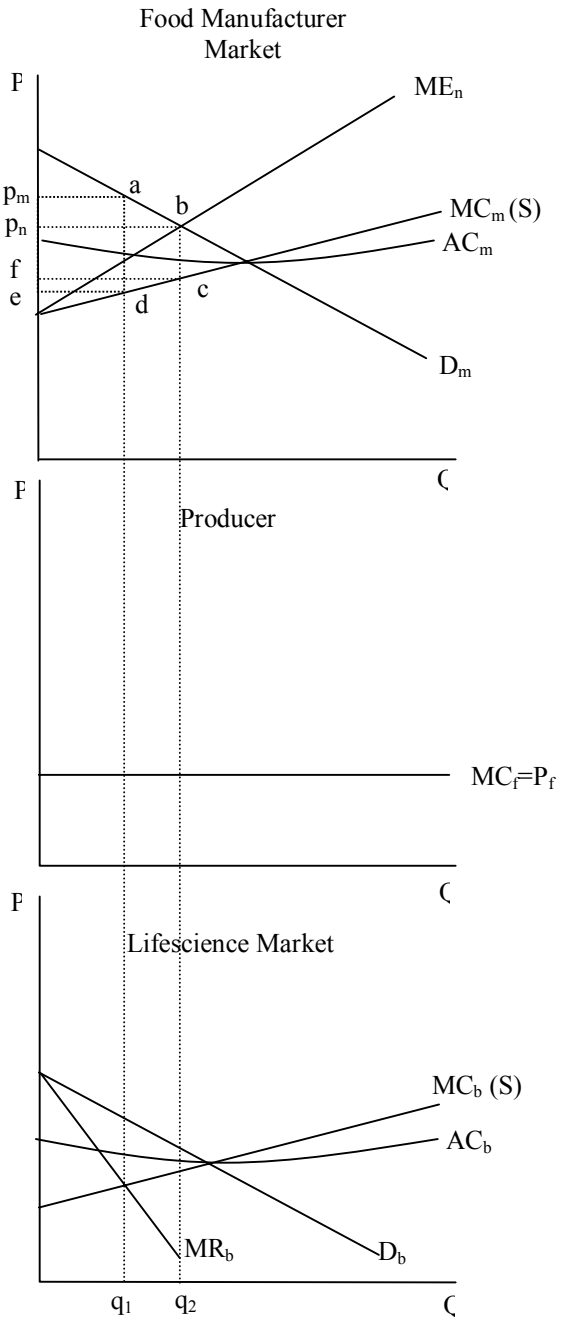

Figure 3.1. The vertical market for GM functional foods

The lifescience firm is assumed to be a monopoly, because they own exclusive rights to the seed technology as a result of patents on the genetics. The assumption is not unreasonable given that it would make sense intuitively that only one firm market the

seed. The lifescience firm sets its quantity through a derived demand function constructed from the demand that the food manufacturer faces. The derived demand that the lifescience firm faces (D_b) is equivalent to D_m - p_f shown in Figure 3.1. The lifescience firm, being a monopoly, will maximize its profits if it sets quantity at the point where marginal revenue equals marginal cost. In Figure 3.1, the optimal quantity for the lifescience firm to produce is q_1. If the quantity is set at the optimal level for the monopoly lifescience firm, the total rents distributed between the lifescience firm and the food manufacturer through bargaining will be equal to area $p_m$ade.

The supply chain is further complicated because the food manufacturer is assumed to have monopsonistic power. The monopsony situation is shown in Figure 3.1. The food manufacturer will have a different objective function than the monopoly lifescience firm. The monopsony food manufacturer will set optimal quantity from the marginal expenditure curve (ME_n), which is derived from the supply curve. The optimal quantity is set where ME_n is equal to D_m and is equal to q_2. The optimal price for the monopsonist to charge the consumer then becomes p_n. The price that the monopsonist pays the producer is shown by point f. The rent available for negotiation in the supply chain is equal to area $p_n$bcf under the optimal solution for the monopsonist.

This situation is known as a bilateral monopoly, and the number of possible solutions is large. The lifescience firm and the food manufacturer will have to bargain over both the quantity and price. The final quantity will be between q_1 and q_2 and the final consumer price will be between p_n and p_m. The final solution will depend on the relative bargaining power of the two firms involved. Once the firms agree on a price and quantity, they must bargain over the distribution of the resulting rent.

The lifescience firm is a monopoly, and can exert some market power given that there may be more than one food manufacturer involved in the initial negotiations. Following the initial contract, the food manufacturer could gain exclusive access to the GM functional food and therefore gain monopsony power. Initially, the food manufacturer will not enter into a contract where they make lower profits than their next best alternative. An outside option in this case is to continue to produce conventional foods, assuming that the food manufacturer is already established. Therefore, there will be a balance in distributing the rents so that both the food manufacturer and the lifescience firm have an incentive to invest.

The potential set back occurs if the cost of R&D plus licensing costs for the lifescience firm is not recovered from the rents gained from consumers. The lifescience firm passes its costs to the grower in the form of a fee for use. The grower must pay this fee and incur additional handling and management costs because of the special care required to ensure the functional trait is passed onto the food manufacturer. In order for the grower to consider growing the GM functional food, they will have to be compensated for their extra costs by the food manufacturer. The food manufacturer will have to make a premium from the GM functional food at least large enough to compensate the grower and leave them as well off as they would be with an alternate product. Using backward induction, if the lifescience firm realizes that the food manufacturer has no incentive to develop GM functional food products, it will hold back future resources that might otherwise be committed toward developing new technologies. The bilateral monopoly situation within a vertical market setting frames the discussion of the three sources of delays to commercialization that follows.

3.2 The effect of government policy uncertainty on the expected profits of the monopolist

Recall that section 2.3 gives an overview of some of the regulations that are in place in Canada, the US and the EU. It also discusses some of the uncertainty and regulatory limbo for functional foods, especially in Canada. This section develops a model to explain the effect that the regulatory uncertainty has on the expected profit of the monopolist lifescience firm and the effect this has on the decision to innovate.

The lifescience firm has the objective function to maximize profits. The simple objective function can be written as follows:

$$\pi_b = P(Q_b;...)Q_b - C(Q_b) - I \tag{16}$$

In this case π_b is the profit the lifescience firm receives from the innovation. $P(Q_b;...)$ represents the derived demand curve for the GM functional food. It is derived by calculating the difference between the demand that the food manufacturer faces (D_m) and the price the producer receives (MC_f=P_f). $C(Q_b)$ is the cost that the lifescience firm faces, with the exception of the fixed R&D costs which are represented by *I*.

However, investments in R&D are never made with certainty that there will be success. The investment is made based on the expectation that the profits gained will be larger than the investment made into R&D. If there were a single firm competing in R&D the objective function of the firm would be:

$$E\pi_b = \alpha\left[P(Q_b;...)Q_b - C(Q_b)\right] - I \tag{17}$$[14]

In this case, α ($\alpha \in [0,1]$) represents the probability that the R&D will result in the successful development of a GM functional food, and the profit function becomes an

[14] This equation was adapted from Shy, 1995.

expectation. The lifescience firm bases the investment decision on the following requirements:

$$Investment = \begin{cases} I & if \alpha[P(Q_b;...)Q_b - C(Q_b)] \geq I \\ 0 & otherwise \end{cases} \tag{18}$$

The firm will invest in the R&D if the probability of success multiplied by firm profit is greater than the level of investment put into R&D. However, normally there is more than one firm competing to develop and patent a technology first. In a situation where there are two firms competing to innovate first, the expected profit for firm i would be:

$$E\pi_{bi} = \alpha(1-\alpha)[P(Q_b;...)Q_{bi} - C(Q_{bi})] + \frac{\alpha^2[P(Q_b;...)Q_{bi} - C(Q_{bi})]}{2} - I \tag{19}$$

In this expected profit function, $\alpha(1-\alpha)[P(Q_b;...)Q_{bi} - C(Q_{bi})]$ represents only firm i being successful in R&D, while $\frac{\alpha^2[P(Q_b;...)Q_{bi} - C(Q_{bi})]}{2}$ represents both firms being successful. For both firms to invest in R&D, it is sufficient for the following condition to hold:

$$\frac{\alpha(2-\alpha)[P(Q_b;...)Q_{bi} - C(Q_{bi})]}{2} \geq I \tag{20}$$

If the condition is satisfied, each firm will invest an equivalent amount in R&D equal to *I*. The expected profit in the case where there is a single firm will be greater than or equal to the expected profit in the case where there are two firms if the following condition holds:

$$[P(Q_b;...)Q_{bi} - C(Q_{bi})] \geq \frac{2}{(2-\alpha)} \tag{21}$$

Intuitively, one would hypothesize that as the number of firms competing to innovate increases, the expected profit from investing in R&D for each firm will decrease. This is the case with this model.

The key parameter in this model is α. One would expect that there would be a negative relationship between the level of regulatory uncertainty and the value of α. This means that when the regulatory uncertainty is high, the lifescience firm will expect the probability of successful commercialization of an innovation to decrease. This will result in a lower expected profit. Similar to the explanation in section 3.1, the profits or rents, must be bargained over between the food manufacturer and the lifescience firm. The expected rents of the lifescience firm must be high enough to compensate for the amount spent on research and development, or the firm will have no incentive to invest.

Another key component that is omitted from this model is time. Another part of government regulatory uncertainty that is important to innovators is the potential for delays in the regulatory process. As the time to approval lengthens, the potential product lifespan and returns on investment decrease. Also, competitors have more time to innovate and develop competing products. If time was included in this model the expected profit would be further reduced when government regulatory uncertainty increased.

3.3 The consumer and branding problem[15]

For the purposes of this analysis, it is useful to view the consumers who are consuming the product as having heterogeneous preferences. A useful instrument for this

[15] This section has been developed with reference to Fulton and Giannakas, 2004 and Giannakas and Fulton, 2002. Also guidance was received from Dr. Murray Fulton, Professor, Department of Agricultural Economics, University of Saskatchewan.

analysis is the address model discussed by Hotelling (1929). Variations of this model have been used to model several problems. It has been used specifically to model heterogeneous consumer preferences towards GM foods (Fulton and Giannakas, 2004; Giannakas and Fulton, 2002). This is the type of model that will be used to show consumer demand for GM functional foods.

The heterogeneous consumer model abstracts from the vertical market model in Figures 3.1, 3.8 and 3.9. This is because the heterogeneous consumer preference model has more competitive market features compared to the bilateral monopoly shown in the vertical market models. The heterogeneous consumer model has no strategic interaction or strategic pricing. This could be a potential limitation of the model.

The prices discussed in the heterogeneous consumer model are assumed to be equal to marginal cost. Therefore, it would follow that if the cost of bringing a product to market increases, the price of the good would increase as well. It will be assumed that the marginal cost for each good is equivalent to the values of "*P*" discussed in this section.

For the analysis, the market will be assumed to consist of a three goods. One of these goods is the GM functional food produced by a national brand firm. The second good is a conventional good produced by a national brand food firm, and the third is a conventional food that is a substitute for the other two. Consumers choose the goods according to the base utility they provide and the price of the goods. The consumers in this model are differentiated by the characteristic c, where $c \in [0,1]$. The characteristic c captures the differences in willingness to pay between consumers.

The first model expresses a different situation than, the national branded conventional good and the substitute good. This scenario is shown in Figure 3.2. In this

two-good market, the share of the substitute is equal to S_S, while the share of the national brand conventional good is S_A. The utility gained from consuming the respective goods are calculated as follows.

$$U_S = \overline{U}_S - P_S - \gamma c \tag{7}$$

$$U_A = \overline{U}_A - P_A - \lambda(1-c) \tag{8}$$

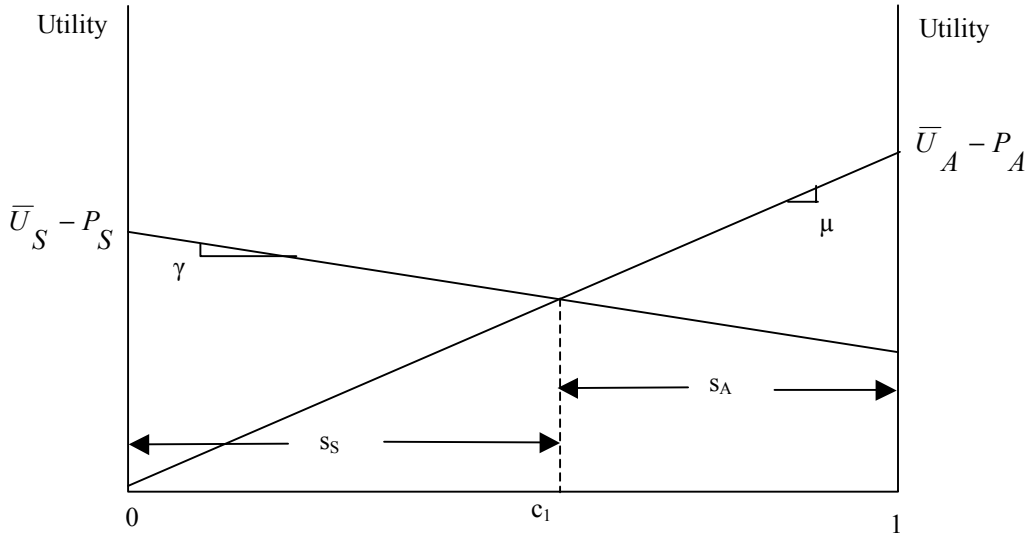

Figure 3.2. Two-good market prior to GM functional food introduction

The variables $\overline{U}_S$ and $\overline{U}_A$ represent the base utility that consumers receive from consuming the substitute and national brand good respectively, while P_S and P_A are their respective prices. The base utilities will differ according to the value that is associated with consuming a national brand or substitute branded product. The non-negative factors discounting the differentiating characteristic of the consumer are γ for the substitute good and λ for the national brand good.

Figure 3.2 shows the relationship between total utility, shown on the vertical axes, and the differentiated consumer characteristic *c,* shown on the horizontal axis. The horizontal axis can be viewed as the range of consumer characteristics. At any given value of *c* the consumer will choose the good which maximizes their utility. The marginal consumer exists at point c_1 in Figure 3.2. This consumer is indifferent about whether to consume the conventional food or the substitute. All the consumers with c values between 0 and c_1 will consume the substitute food in this case, while those between c_1 and 1 will consume the conventional food.

To determine the respective shares of the two goods, U_A is equated to U_S. The intersection point is formed as a result. This point is equivalent to c_1 on the horizontal axis. The market shares of the two goods are represented by S_A and S_S for the national branded conventional product and the substitute respectively. S_S is equal to the distance between 0 and c_1, while S_A is equivalent to the distance between c_1 and 1. The goods are substitutes; therefore the shares depend on the relative base utility gained from consumption, the relative prices of the two goods and the discount factors.

$$S_S = c_1 = \frac{\overline{U}_S - \overline{U}_A + P_A - P_S + \lambda}{\lambda + \gamma} \tag{9}$$

$$S_A = 1 - c_1 = \frac{\overline{U}_A - \overline{U}_S + P_S - P_A + \gamma}{\lambda + \gamma} \tag{10}$$

The interest to this thesis is the effect of introducing a GM functional food to the market. It will be assumed that the firm owning the national brand introduces the GM functional food as part of its brand offering. It is also possible that the substitute firm, or a new entrant to the market could introduce the GM functional food. The total utility a consumer receives from consuming the functional food is shown by Equation 11. In this

case $\overline{U}_F$ is the base utility from consuming a GM functional food, P_F is the price and μ is the discount factor on the differentiated consumer attribute c. It is important to consider what proportion of the GM functional food will be purchased by the core national brand consumers, and what proportion will be consumed by new consumers who substitute away from the substitute product.

$$U_F = \overline{U}_F - P_F - \mu(1-c) \tag{11}$$

If Figure 3.2 is compared to Figure 3.3, the effect of the addition of the functional food can be seen. Now there is a third share that is included in the market. S_F represents the share of the GM functional food. Note that the share of both the national branded conventional food and the substitute are reduced with the introduction of the GM functional food. The respective shares are found by equating the utility curves to find the corresponding c value of the intersection points. The intersection points of interest are shown in Figure 3.3 as c_1 and c_2.

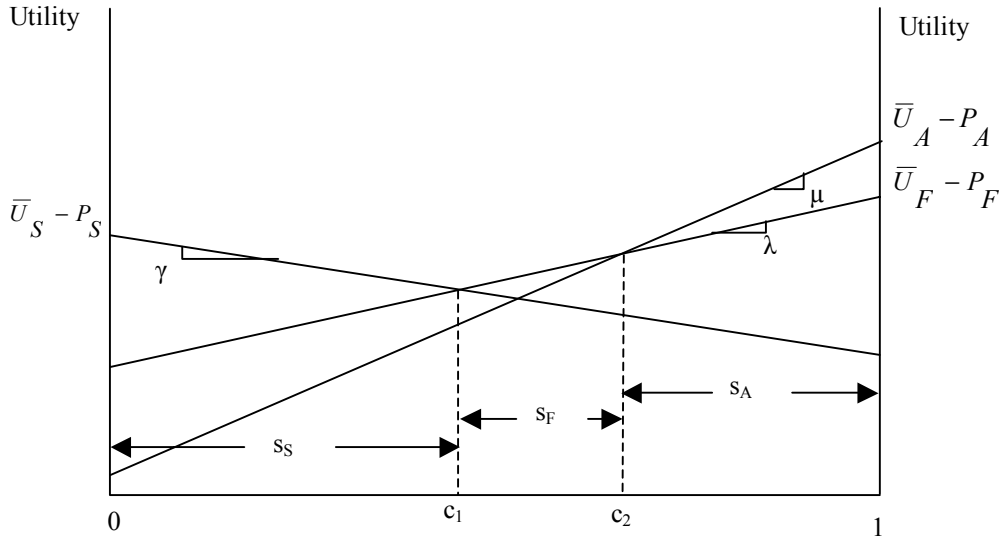

Figure 3.3. Three-good market following introduction of GM functional food

The distance between the intersection points or points of indifference are the respective market shares.

$$S_S = c_1 = \frac{\overline{U}_S - \overline{U}_F + P_F - P_S + \mu}{\gamma + \mu} \tag{12}$$

The market share of the national brand conventional food is equal to the difference between 1 and the intersection point represented by c_2.

$$c_2 = \frac{\overline{U}_F - \overline{U}_A + P_A - P_F + \lambda - \mu}{\lambda - \mu} \tag{13}$$

$$S_A = 1 - c_2 = \frac{\overline{U}_A - \overline{U}_F + P_F - P_A}{\lambda - \mu} \tag{14}$$

The remaining market share is taken by the GM functional food. It is calculated by taking the difference between the intersection points c_2 and c_1.

$$S_F = c_2 - c_1 = \frac{(\gamma+\lambda)\overline{U}_F - (\gamma+\mu)\overline{U}_A - (\lambda-\mu)\overline{U}_S + (\gamma+\mu)P_A + (\lambda-\mu)P_S - (\gamma+\lambda)P_F + \gamma(\lambda-\mu)}{(\lambda-\mu)(\gamma+\mu)} \tag{15}$$

The national brand firm will be interested in the effect that the introduction of the GM functional food will have on the brand as a whole. In this case it will be the effect on the national brand's conventional food. This can be measured by the change in the base utility ($\overline{U}_A$) from consumption of the conventional food after the introduction of the GM functional food. For example, consider a case where there is negative press concerning the association between the national brand firm and a lifescience firm in the production of the GM functional food. This would lower the base utility for the GM functional food ($\overline{U}_F$) along with $\overline{U}_A$ because of consumer backlash towards the brand as a whole. This

would result in a shift down of the utility curves for the GM functional food and the conventional food as shown in Figure 3.4.

In Figure 3.4, the change in the market share of the conventional food is reduced to S_A'. However, the extent of this reduction depends on the change in $\overline{U}_A$' relative to the change in $\overline{U}_F$'. A specific problem with the GM functional food, such as a batch with bad flavour, might lower the base utility of the GM functional food substantially relative to the conventional food. Alternatively, a food safety concern involving the GM functional food, such as negative health effects of the functional characteristic, could lower the base utilities of consuming the GM functional food and the conventional food because of the tainted brand image. In any case, the total market share of the national brand, including the GM functional food and the conventional food will be reduced by $c_1' - c_1$ in Figure 3.4. Firms contemplating manufacturing GM functional food will not only be concerned with the change in market share in Figure 3.4, but also how that relates to the market share they have in Figure 3.2, before they expand their brand to include GM functional foods.

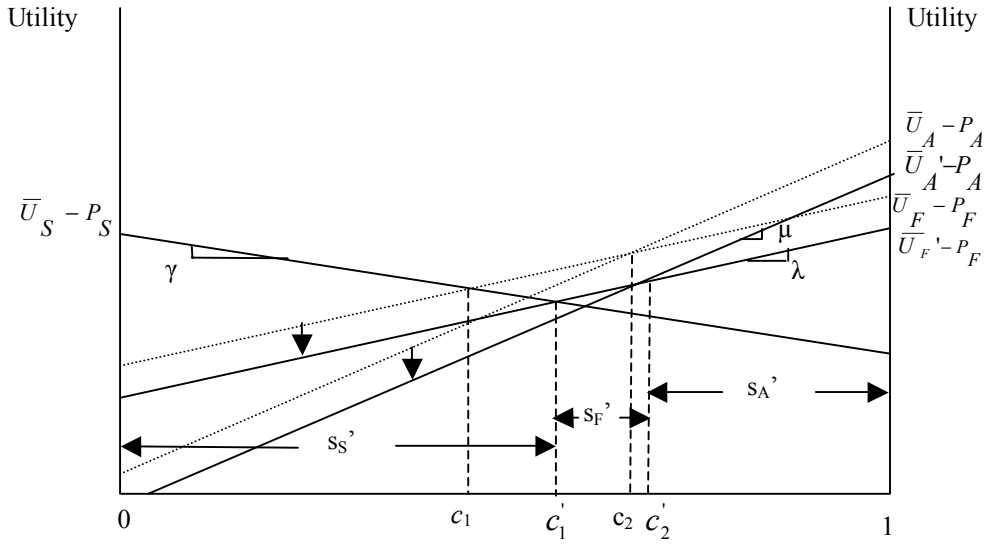

Figure 3.4. The results of a problem which damages the brand image

The base utility values for the conventional food and the GM functional food can be looked at as the method of conveying the effects discussed by Cabral (2000). At the initial introduction of the GM functional food, the *direct reputation effect* that the national brand has affects the initial willingness-to-pay of the consumer. After consumers have some experience with the GM functional food (personal and knowledge gained through media), the *feedback reputation effect* influences the willingness-to-pay for both the GM functional food and the conventional food. Finally, the overall image of the brand in terms of firm quality is influenced by the *signalling effect.* All of these effects will be signalled through the base utility that consumers have for the national brand firm's products.

The introduction of the GM functional food could have the opposite effect on the market shares of the conventional and GM functional food, if the situation is reversed in

Figure 3.4. If the utility curves shift up as a result of an increase in base utility from $\overline{U}_F$' to $\overline{U}_F$ for the functional food and $\overline{U}_A$' to $\overline{U}_A$ for the conventional food, the firm will realize a definite benefit from introducing the GM functional food. This type of change would be realized if the introduction of the functional food provided a positive *feedback reputation effect* and *signalling effect* towards the value of the brand, and in turn the products it offers.

In cases where the food manufacturer predicts that they will gain no market share for the GM functional food, it will not be introduced. This is the situation shown in Figure 3.5. There are a couple of main causes that can alone or in combination cause this scenario to take place. First, if the GM functional food does not provide a significant enough health benefit to raise $\overline{U}_F$ high enough in comparison to $\overline{U}_A$ to compensate for the price difference between the two goods, it will not gain demand. Second, even if the GM functional food provides a significant health benefit, if the cost to bring to the market and in turn the price is too high, there will be no market demand. Also a combination of these two factors could lead to zero market share for the functional food as shown in Figure 3.5. In this case there is no incentive for the national brand firm to introduce the product. Finally, the firm will have to make enough additional revenue from the addition in market share resulting from the introduction of the GM functional food to compensate for the increase in costs.

The situation shown in Figure 3.5 could also occur following the product introduction. If the GM functional food does not provide a functional characteristic that satisfies the health claim it makes, consumers will be unwilling to pay a premium price to purchase the food. Also, if the food has undesirable characteristics such as poor flavour,

the base utility of consumers who originally valued the health quality will diminish. All of these factors will cause a decrease in the value of $\overline{U}_F - P_F$, resulting in a reduction in market share and eventually zero market share as shown in Figure 3.5. This can also be linked to the regulatory uncertainty that exists. A similar effect on the value of $\overline{U}_F$ would occur if the food were unable to make the health claim required to increase its value.

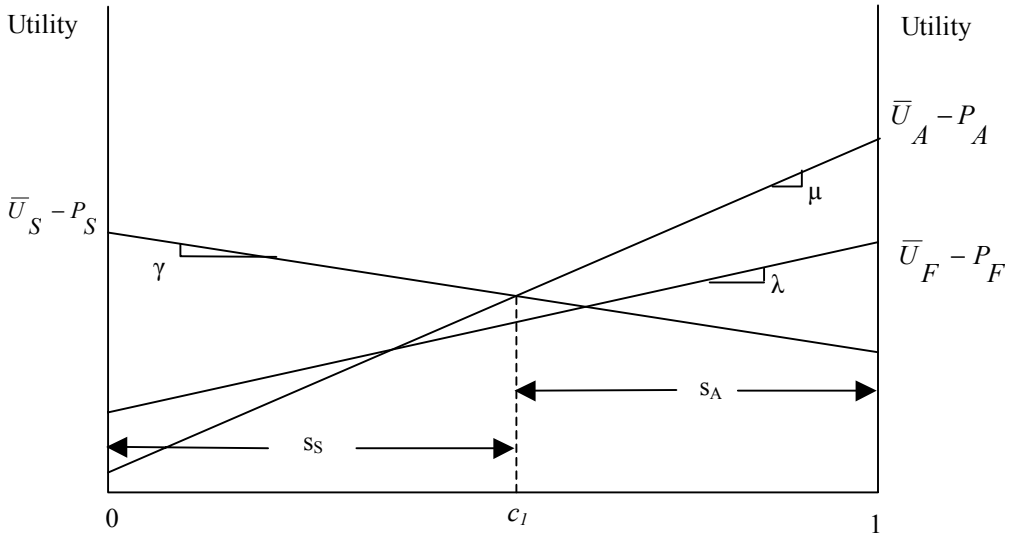

Figure 3.5. The case in which the GM functional food carries zero market share

An important factor is the demand for the functional attribute that the GM functional food provides to the consumer, and the effectiveness of the product itself. In this model the functional attribute will affect the base utility ($\overline{U}_F^{"}$) that the product provides the consumer. The effects on market share of the GM functional foods caused by a boost to the value of $\overline{U}_F - P_F$ *ceteris paribus* is shown in Figure 3.6. In this situation, the share S_F increases, the share S_S decreases and the share S_A decreases substantially. This situation shows that the firm marketing the GM functional food will

want to do research into attributes that target health issues that consumers place a high value on.

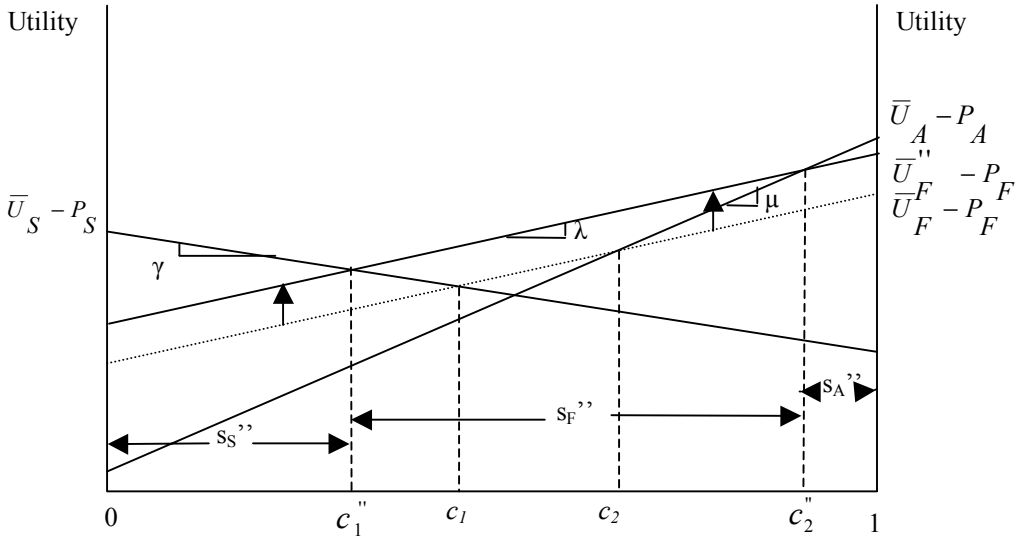

Figure 3.6. The effect of a highly demanded functional trait or price reduction on the GM functional food

Another cause of the shift shown in Figure 3.6 is the reduction in price of the GM functional food. Even if the consumers do not find the functional characteristic overly attractive, they might purchase it if the premium is small. However, the food manufacturer producing the GM functional food will want an increase in market share to be due to a boost in base utility, or a change in the discount factor. If increased market share is as a result of a price decrease, it means the price is closer to the price of the conventional food. Since it is assumed that the two are under the same brand and the largest gain in the market share of the functional food is gained from the conventional food, the manufacturer will hope that gain will result in higher margins. If the transfer of

market share from the conventional food to the GM functional food does not result in higher margins, the firm will only gain from the market share gained from the substitute good. Also, this model does not take into account the additional research and development cost of producing the GM functional food. If the main effect is a change in market share from the conventional food to the GM functional food without an increase in the margin the food processor is able to receive, it will not be an attractive investment for the firm.

Another factor to take into consideration that will have an effect on the market shares of the respective goods is their relative prices. Since total utility is the difference between the base utility and the price, excluding the differentiating characteristic, if the price increases it will result in a shift down of the utility curve. In Figure 3.6, an increase in the price of the GM functional food *ceteris paribus* will cause a shift down in the utility curve for the GM functional food. If large enough, the effect could be a shift from $\overline{U}_F''-P_F$ to $\overline{U}_F - P_F$. This shows that for any one product to succeed there is a balance that must be struck between the base utility, price and discount factor so that a market share is attainable to provide a sustainable return.

The discount factors will also have an effect on the size of the market shares that are available to all firms. If the discount parameters of either γ, λ or μ increases *ceteris paribus*, the market share of the respective product will decrease. The value of the discount parameter will be affected by the perceived quality of the product. For example, the GM functional food shares several characteristics with the conventional product under the same brand. However, the discount parameter is smaller because of the additional health benefits it provides. If the health benefits for the functional food are

small, its discount parameter will be closer to the value of the discount parameter of the conventional food. Another factor that will have an effect is taste. Consumers want a food that tastes good. The GM food could have a good health benefit, but if it does not taste good the discount parameter will increase closer to that of the conventional alternative.

Recall that the value of c is the individual's unique characteristic that affects their willingness to pay, which is discounted by the parameters γ, λ or μ. If the discount parameters increase, the slope of the utility curve will increase in absolute terms. No matter which parameter increases, *ceteris paribus*, the share of that good will decrease. This case is shown below in Figure 3.7. The situation from Figure 3.6 is altered so that μ increases *ceteris paribus*. The total utility at the right axis is still equal to $\bar{U}_F''-P_F$; however because of the increase in μ the share of the GM functional food decreases to S_F'''. The shares of the other two goods increase as a result. The share of the substitute (S_S''') increases by the difference between c_1''' and c_1'', while the share of the conventional food (S_A''') increases by the difference between c_2'' and c_2'''.

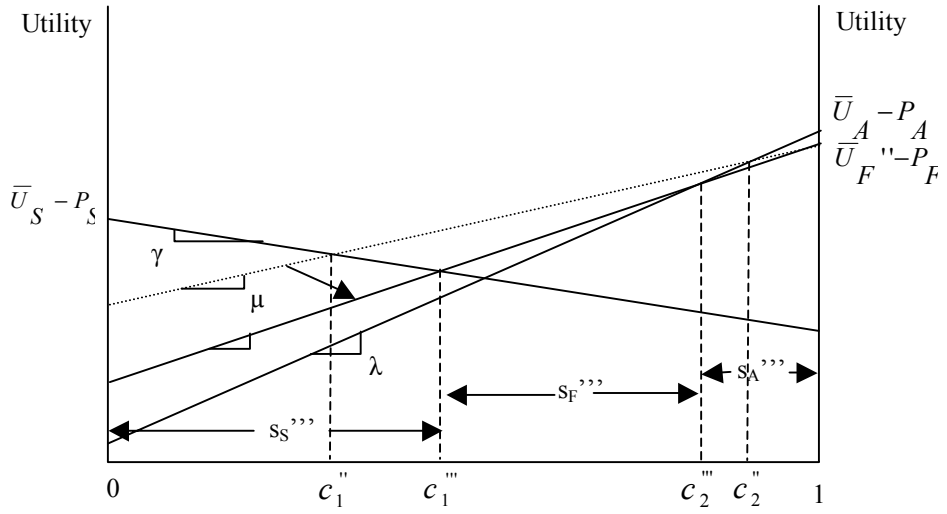

Figure 3.7. The effect of a change in the discount factor on market share

It is important to note that this model has only considered only GM functional food introduction by a national brand firm. The national brand firm must consider the effect of the new food on the firm as a whole. Another situation that could be analysed is if the GM functional food was introduced by a new entrant to the industry. If a new entrant introduced the GM functional food, the considerations with respect to the change in aggregate firm revenue compared to costs would not arise. The new entrant would solely be concerned with the market share that could be gained for the GM functional food.

The analysis of this model also assumes that the size of the "pie" to be divided among the brands is constant. In fact, a new brand could in theory increase the size of the "pie". The result of this increase would be the market share of a given brand could

decrease, but that would not necessarily correspond in a decrease in demand for that product.

3.4 Numerical simulation of the consumer and branding problem

To further facilitate the understanding of the model developed in Section 3.3, it is valuable to perform some numerical simulation. The simulation was performed using the Solver tool in Microsoft Excel. The purpose of the model is to show numerically the effect of changes in the variables and parameters on the market share of the functional food.

The simulation results are shown in Tables 3.2 and 3.3[16]. Since there are no commercialized GM functional foods in the marketplace at this time, it was necessary to use hypothetical values to determine the potential market shares of the three goods. The main purpose of the simulation model is to conduct sensitivity analysis in order to determine what effect changes in the base utility, price and discount factor for the functional food will have on its market share, while holding the values equal for the conventional and substitute goods constant.

The product that is examined in the simulation model is tomato paste. This product is used because it is realistically one of the products that could be developed as a GM functional food. There are studies underway, as mentioned previously, to increase the lycopene levels in tomatoes through transgenics. Also, one of the cases in the next chapter discusses tomato paste. The case illustrates a GM tomato paste that was sold under private label in the United Kingdom with some success, but removed from the

[16] The methodology used to perform the simulation is shown in the appendix to the thesis.

market because of increased opposition to GM foods. Another reason for the choice of tomato paste is that there is little to differentiate between when choosing a tomato paste besides the brand, and potentially if there is a functional characteristic.

The prices for the GM functional food are all hypothetical; however the prices for the conventional and substitute goods are actual prices gathered from a Safeway grocery store in Saskatoon, Saskatchewan in 2005. For the purposes of the simulation analysis, it will be assumed that there are only two firms in the market for tomato paste. The first is the conventional product, which in this case will be the national brand product. It had an in-store price of $0.99 per 156 ml can. The substitute product will be the store's own-brand tomato paste. The in-store price of the own-brand tomato paste was $0.75 per 156 ml can. For the simulation model, these prices were converted to $0.63 and $0.48 per 100 ml respectively.

Table 3.1 shows the initial situation that is used in the two-good market prior to the introduction of the GM functional tomato paste. The two scenarios are a two-good market with a 50-50 market share originally and a two-good market with a 70-30 market share originally. In the latter scenario the firm with the 70% market share introduces the GM functional food. In both cases the national brand is assumed to introduce the functional food, similar to the theoretical model.

Table 3.1. The original two-good market prior to introduction of the GM functional food.

Situation	$\tilde{U}_A$	P_A	λ	$\tilde{U}_S$	P_S	γ	S_A	S_S
2 Goods - 50-50 Market	3.5769	0.63	1.00	3.4231	0.48	1.00	0.500	0.500
2 Goods - 70-30 Market	3.6428	0.63	0.50	3.3572	0.48	0.73	0.700	0.300

In the 50-50 market share scenario, the national branded tomato paste has a higher base utility ($\overline{U}_A$ = 3.5769) compared to the substitute tomato paste ($\overline{U}_S$ = 3.4231), but also had a price (P_A) that was \$0.15/100ml higher than that of the substitute (P_S). Therefore the total utility on the left and right axes (see any of Figures 3.2 to 3.9 for visual graph) were equivalent. The discount factors λ and γ were each equivalent to 1, which was the maximum value these parameters were restricted to.

In the 70-30 market share scenario, the national branded tomato paste begins with a 70% market share (S_A), while the substitute tomato paste has a 50% market share (S_S). The base utility of the national brand tomato paste ($\overline{U}_A$) was 3.6428, while the base utility of the substitute ($\overline{U}_S$) was 3.3572. The discount factors λ and γ were equal to 0.50 and 0.73 respectively. The prices (P_A and P_S) in this scenario are equivalent to those in the 50-50 scenario.

The values in the two-good market remain static throughout the respective scenarios, with exception to the market shares of the two goods (S_A *and* S_S). The price values explained earlier were inserted to the model, and the remainder of the values were generated using Solver in order to give the desired two-good market share prior to introduction of the GM functional food to the market.

3.4.1 Simulation with market shares of 50-50

The first situation examined a situation where the conventional and substitute goods equally divided the market prior to the introduction of the GM functional tomato paste. The values generated to give a 50-50 market share scenario in the two-good market

were then transferred to a similar model set up for the three-good market. The values for the functional tomato paste were generated to achieve a 10% market share, which also affected the market share of the original two goods. The results are shown in Table 3.2.

Table 3.2. Scenario 1: 50/50 original market share

		Variable											
	Situation	$\tilde{U}_F$	P_F	μ	$\tilde{U}_A$	P_A	λ	$\tilde{U}_S$	P_S	γ	S_F	S_A	S_S
1	Base	3.5769	1.08	0.01	3.5769	0.63	1.00	3.4231	0.48	1.00	0.100	0.449	0.451
2	$\tilde{U}_F$ up 1.0%	3.6127	1.08	0.01	3.5769	0.63	1.00	3.4231	0.48	1.00	0.172	0.413	0.415
3	$\tilde{U}_F$ up 5.0%	3.7558	1.08	0.01	3.5769	0.63	1.00	3.4231	0.48	1.00	0.458	0.268	0.274
4	$\tilde{U}_A$ where S_F=0	3.5269	1.08	0.01	3.5769	0.63	1.00	3.4231	0.48	1.00	0	0.500	0.500
5	P_F 50% Premium	3.5769	0.95	0.01	3.5769	0.63	1.00	3.4231	0.48	1.00	0.354	0.321	0.325
6	P_F where S_F=0	3.5769	1.13	0.01	3.5769	0.63	1.00	3.4231	0.48	1.00	0	0.500	0.500
7	μ = 0.1 (Base #2)	3.6127	1.08	0.10	3.5769	0.63	1.00	3.4231	0.48	1.00	0.083	0.452	0.462
8	μ = 0 (Base #2)	3.6127	1.08	0.00	3.5769	0.63	1.00	3.4231	0.48	1.00	0.183	0.408	0.409
9	μ where S_F=0 (Base #2)	3.6127	1.08	0.18	3.5769	0.63	1.00	3.4231	0.48	1.00	0	0.500	0.500

The scenario which would give the GM functional tomato paste a 10% market share was then solved for keeping the values for the two other goods constant. The base utility of the GM functional tomato paste was equivalent to that of the conventional tomato paste under the same brand ($\overline{U}_F$ = 3.5769). This base utility can be explained as capturing the value that the consumers place on the brand. Therefore, intuitively it makes sense that it would be equivalent at initial introduction as a result of the *direct reputation* effect. The generated price of the functional tomato paste is substantially higher than either the conventional or substitute tomato paste. The price (P_F) is \$1.08/100ml which is a 71% premium over the conventional food. This premium is offset by a much lower discount rate (μ) equal to 0.01 compared to the discount rate of 1 for the other two goods. The discount rate is lower because of the functional characteristic the functional tomato

paste provides the consumer. The solution was set up to give a share to the GM functional tomato paste (s_F) of 10%. The market shares of the other goods were each reduced from 50% to 44.9% for the conventional tomato paste (s_A) and 45.1% for the substitute tomato paste (s_S).

Several shocks are then introduced to this base case, keeping the prices, base utilities and discount parameters of the conventional and substitute goods constant. These shocks are listed as the Situations from 2 through 9 in Table 3.2. The values that changed in these situations are shaded in grey in the table. Situation 2 raised the base utility of the functional food by 1% to observe the effect on the market shares of the three goods. The increase changes the base utility of the functional food to 3.6127 from 3.5769. This could be the result of positive consumer experiences as a result of consuming the functional tomato paste. The result of this boost in base utility is an increase in market share (s_F) from 10% to just over 17%. The market share of the conventional tomato paste (s_A) decreases from 44.9% to 41.3% and the market share of the substitute tomato paste (s_S) decreases from 45.1% to 41.5%. Situation 3 in Scenario 1 shows the impact of a 5% increase in the base utility of the functional tomato paste. The base utility of the functional tomato paste becomes 3.7558. This increases the market share of the functional tomato paste to 45.8%, while the market shares of the conventional tomato paste and substitute tomato paste fall to 26.8% and 27.4% respectively. Also of interest was the base utility under this scenario that would cause the share of the functional tomato paste to become zero. The results are shown in Situation 4 in Table 3.2. The base

utility value that causes the market share of the functional tomato paste to become zero was 3.5269 which was a 1.4% decrease from the base scenario.

The next set of sensitivities was performed by changing the price of the functional tomato paste, while keeping all the other variables constant. As stated earlier, the base scenario had a price premium of 71%. First the price was reduced so that it was only at a 50% premium to the conventional tomato paste (Situation 5 in Table 3.2). The new price was \$0.95/100ml compared to \$1.08/100 ml. The result of this change was an increase to 35.4% market share from 10% market share for the functional tomato paste, a reduction from 44.9% to 32.1% for the conventional tomato paste and from 45.1% to 32.5% for the substitute tomato paste. Also, it was important to determine the price that would cause the market share of the functional tomato paste to become zero (Situation 6 in Table 3.2). The solution showed that if the price of the tomato paste (P_F) increased from \$1.08 to \$1.13/100ml under the base scenario, the share of the functional tomato paste would become zero, and the share of the other two goods would become 50% apiece.

Finally, the effect of the discount parameter μ was simulated in the model (Situations 7, 8 and 9 in Table 3.2). The original value of μ was 0.01. The value of μ was adjusted to be 0.1 and the effects on the market shares of the three goods were measured. It is important to note that a different base situation was used for this calculation. The new base is Situation 2 in Table 3.2 where the base utility of the functional tomato paste is increased by 1% (recall that the original base was Situation 1 in Table 3.2). This is because basically no change in μ was possible without creating zero market share for the functional tomato paste under the original base situation. The effect of the increase in μ is

a decrease of the market share of the functional tomato paste from 17.2% (Situation 2 in Table 3.2) to 8.3% (Situation 7 in Table 3.2). The conventional tomato paste market share increased to 45.2% (Situation 2 in Table 3.2) from 41.3% (Situation 7 in Table 3.2), while the market share of the substitute increased from 41.5% (Situation 2 in Table 3.2) to 46.2% (Situation 7 in Table 3.2).

The next test was to determine what the market share of the functional tomato paste would be if the value of μ were zero. The result was a market share of 18.3% for the functional tomato paste, 40.8% for the conventional and 40.9% for the substitute (Situation 8 in Table 3.2). The value of μ that resulted in zero market share for the GM functional food was also calculated (Situation 9 in Scenario 1). The result was a μ value of 0.18. Once again this leads to each of the conventional and substitute tomato paste products holding a 50% market share.

Overall, under the scenarios solved with the two firms initially holding a 50% market share we can show the sensitivity the model shows towards change. A small shock to the base utility, or discount parameter led to a relatively large change in market shares. If the market for tomato paste was sensitive similar to this simulation, there would be a lot of risk to the food manufacturer. Any change in consumer perceptions regarding the GM functional food will have a large effect on not only the share of that product, but also on their conventional product. It is also useful to start with a different base situation. The next sub-section will start with the market share divided with the conventional tomato paste holding 70% and the substitute tomato paste holding 30%.

3.4.2 Simulation with market shares of 70-30

The simulations completed with the original market shares of the conventional and substitute tomato pastes holding respective market shares of 70% and 30% were carried out with the same methodology as the previous sub-section. The results are shown in Situations 10 through 18 under Scenario 2 in Table 3.3. Some of the shocks were introduced slightly different because the same shocks in the first model did not fit well in this scenario. Once again the GM functional tomato paste was added to the original market and the situation solved so that it gained an initial 10% market share. The original base utility for the functional tomato paste ($\overline{U}_F$) was equivalent to the base utility of the conventional tomato paste ($\overline{U}_A$), which was a value of 3.6428. The base utility for the substitute tomato paste ($\overline{U}_S$) was 3.3572. The original price of the functional tomato paste (P_F) was \$0.94, which is lower than in the first model, but still about a 50% premium to the price of the conventional tomato paste (P_A). The reason the original price of the functional food was lower in Scenario 2 was that the two-good market was set with different market shares. As a result when Solver calculated the situation that would give the functional food a 10% market share, the price of the GM functional food was lower. The value of the parameters μ, λ and γ were 0.02, 0.50 and 0.73 respectively. Once again, as a result of the functional characteristic, the discount rate for the functional food is much lower than that of the other two goods at 0.02. Under Scenario 2 the situation was simulated that gave the conventional food a higher market share (70%) in the two-good market. As a result the discount parameter of the conventional food became smaller, relative to that of the substitute. With such a large share of the market in the two-good

market, the conventional tomato paste must have been a more popular product with consumers relative to the conventional tomato paste in Scenario 1. For this reason, the explanation for the higher discount rate in the functional tomato paste under Scenario 2 could be that it offers less of an improvement (i.e. health benefits and flavour) in comparison to the conventional tomato paste.

Table 3.3. Scenario 2: 70/30 Original Market Share

		Variable										
	Situation	$\tilde{U}_F$	P_F	μ	$\tilde{U}_A$	P_A	λ	$\tilde{U}_S$	P_S	γ	S_F	S_A	S_S
10	Base	3.6428	0.94	0.02	3.6428	0.63	0.50	3.3572	0.48	0.73	0.100	0.639	0.261
11	$\tilde{U}_F$ up 1.0%	3.6792	0.94	0.02	3.6428	0.63	0.50	3.3572	0.48	0.73	0.224	0.564	0.211
12	$\tilde{U}_F$ up 5.0%	3.8249	0.94	0.02	3.6428	0.63	0.50	3.3572	0.48	0.73	0.721	0.264	0.015
13	$\tilde{U}_A$ where S_F=0	3.6135	0.94	0.02	3.6428	0.63	0.50	3.3572	0.48	0.73	0	0.700	0.300
14	P_F 40% Premium	3.6428	0.89	0.02	3.6428	0.63	0.50	3.3572	0.48	0.73	0.291	0.524	0.185
15	P_F where S_F=0	3.6428	0.97	0.02	3.6428	0.63	0.50	3.3572	0.48	0.73	0	0.700	0.300
16	μ = 0.1 (Base #11)	3.6792	0.94	0.10	3.6428	0.63	0.50	3.3572	0.48	0.73	0.025	0.683	0.292
17	μ = 0 (Base #11)	3.6792	0.94	0.00	3.6428	0.63	0.50	3.3572	0.48	0.73	0.259	0.547	0.195
18	μ where S_F=0 (Base #11)	3.6792	0.94	0.11	3.6428	0.63	0.50	3.3572	0.48	0.73	0	0.700	0.300

Under Scenario 2, the base utility of the functional tomato paste is increased by 1% from 3.6428 to 3.6792, holding everything else equal in Situation 11. The resulting market shares are 22.4% for the functional tomato paste (S_F), 56.4% for the conventional (S_A) and 21.1% for the substitute (S_S). Next, the same procedure was followed to increase the base utility of the functional tomato paste by 5%. This increased the market share of the functional tomato paste to 72.1%, the conventional tomato paste to 26.4% and the substitute tomato paste to 1.5% (Situation 12 in Scenario 2). Also, the solution was found for the base utility of the functional tomato paste that yields a zero market share (Situation 13 in Scenario 2). This was found to be 3.6135, which is a 0.8% decline from the base scenario. Overall, from these changes in utility and the

corresponding changes in market share, it is evident under this second scenario the market share is more sensitive to changes in base utility of the functional tomato paste than in the first scenario.

Next the sensitivity to price change was tested in the model. The original price of the functional tomato paste in the base solution to gain a 10% market share was a 50% premium to the conventional tomato paste. Recall that the premium under the first scenario was 71%. Therefore, for sensitivity purposes the premium was reduced to 40%, rather than 50% which was used in the first scenario. Holding all other variables constant, the reduction in price from $0.94/100ml to $0.89/100ml causes the market share of the functional tomato paste to increase from 10% to 29.1% (Situation 14 in Scenario 2). The market shares of the other two goods fall. The conventional tomato paste falls from 63.9% to 52.4% and the substitute food falls from 26.1% to 18.5%. The price that causes a zero market share for the functional tomato paste is $0.97/100ml which is a 3.2% increase in price from the base situation where the functional tomato paste has a 10% market share (Situation 15 in Scenario 2). Under this situation the conventional and substitute goods revert to the same situation they had in the two-good market. The conventional tomato paste had a 70% market share and the substitute 30%. In the first scenario the increase in price that caused the market share to become zero was 4.6%. These shocks show that under the second scenario, the functional tomato paste is much more sensitive to price shocks than in the first scenario. Intuitively, this makes sense because of the initial market share of the conventional tomato paste. It is evident by the relatively high market share of 70%, that the consumers had a strong preference for that tomato paste prior to the introduction of the functional tomato paste. For this reason,

consumers will shift back to consuming the conventional tomato paste from the functional tomato paste more easily as a result of a price increase than they would under Scenario 1.

Finally, the value of μ was shocked to show the effects on the shares of the three goods. Once again, similar to the first scenario a different base was used for the changes in μ because virtually no change is possible under the original base situation. The base used in this case is Situation 11 in Scenario 2 where the base utility of the functional tomato paste is increased by 1%. The first shock is to increase the value of μ to 0.1 from 0.02 (Situation 16 in Scenario 2). This causes the reduction in market share of the functional tomato paste to 2.5% from 22.4%. The market shares of the other two goods increase to 68.3% from 56.4% and 29.2% from 21.1% for the conventional and substitute tomato paste respectively. The next shock introduced was a change in the value of μ from 0.02 to 0 (Situation 17 in Scenario 2). The decrease in the discount increases the market share of the functional tomato paste to 25.9% from 22.4%. The decrease in market share to the conventional and substitute tomato paste was to 54.7% and 19.5% respectively. Finally the discount value that caused the market share of the functional tomato paste to become zero was calculated (Situation 18 in Scenario 2). The solution was a value of μ of 0.11. At this value, the market shares of the other two goods returned to the two product market values of 70% for the conventional tomato paste and 30% for the substitute. Because the discount parameter for the conventional tomato paste is lower under Scenario 2 than in Scenario 1, the market share of the functional tomato paste is more sensitive to changes in the value of μ.

Overall, under scenario 2 the market share of the GM functional food was more responsive to changes than it was in scenario 1. Small shocks in the value consumers place on the brand, the price of the good and the discount parameter could have a large effect on the market share and corresponding profitability of the functional tomato paste. The next sub-section provides a summary of the two scenarios.

3.4.3 Summary of simulations

Although the conclusions that can be drawn from the simulation analysis are limited as a result of the number of hypothetical values used and the simplicity of the model, there are some generalizations that can be made. First, the sensitivity of the products in the real world probably would be less exaggerated than was shown in this model. However, the relative sensitivities would be similar. It is valuable to see that if the market is divided equally between the original participants, there is much less sensitivity than when the participant introducing the GM functional food has a relatively high market share. If the firm introducing the GM functional food has a high market share in the two good market, they may want to consider that the risk is higher in this case.

These results can be tied to the work by Cabral (2000). In Scenario 2, the national brand firm has the larger market share. We can assume that they are the firm with the highest reputation, through the higher base utility relative to the substitute. Also, the firm would have a higher base utility relative to a new entrant. It a new entrant entered the market, the GM functional food would have to have a lower price and lower discount factor in order to compensate for the lower base utility.

A national brand will find it in their best interest to expand their brand to include the functional tomato paste if that tomato paste provides what consumers will perceive to be a high value health benefit. If there is a high value health benefit, the reputation that the brand has will support the initial reputation of the functional food in the market. This is because a small increase in the base utility or decrease in the discount parameter of the functional tomato paste will have a large beneficial effect on the market share of the national brand firm as a whole. On the other hand, if the functional tomato paste does not offer a substantial health benefit, the downside risk might be too high for the firm to justify expanding their brand.

3.5 The access to intellectual property problem

Finally, an assessment of the access to intellectual property is warranted. The members of the supply chain for GM functional foods will be concerned with the transaction costs involved in acquiring licenses necessary to gain access to intellectual property held by other firms. The firms that own the intellectual property could either be another lifescience firm, who is a competitor, or an upstream biotech firm. As the literature in Chapter 2 explained, in order to gain access to intellectual property firms will either merge with or acquire the owner of the intellectual property, or they will negotiate a license for its use. Either way, the result of having to gain access to the intellectual property can be shown as a shift in the marginal cost. In Figure 3.8, this is shown as a shift in the marginal cost from MC_b to MC_b' in the lifescience market. This is as a result of the extra cost the lifescience firm incurs because of increased transaction costs to negotiate a license with a food manufacturer combined with the actual cost of the

license.[17] The result of this is that the profit maximizing level of output for the lifescience firm decreases from q_1 to q_1'.

The monopsonist food manufacturer also sees a change in their optimal output. The increase in marginal cost of the lifescience firm is passed up the supply chain which is shown as a shift in marginal cost from MC_m to MC_m' in the food manufacturing firm. This also shifts the marginal expenditure of the food manufacturing firm from ME_n to ME_n'. As a result, the food manufacturer will want to reduce output from q_2 to q_2'. Once again the parties will bargain over the distribution of rent by setting price and quantity. However, the rent available for negotiation is smaller in this case as a result of the increased transaction costs.

[17] The license fee itself will either be a one-time payment for use, or a royalty on sales of the product after development. It will be assumed for this analysis that they would have similar effects on the marginal cost. The one-time payment will increase the marginal cost because of the debt that has to be serviced and the royalty will have to be paid on every unit sold, which will increase the marginal cost.

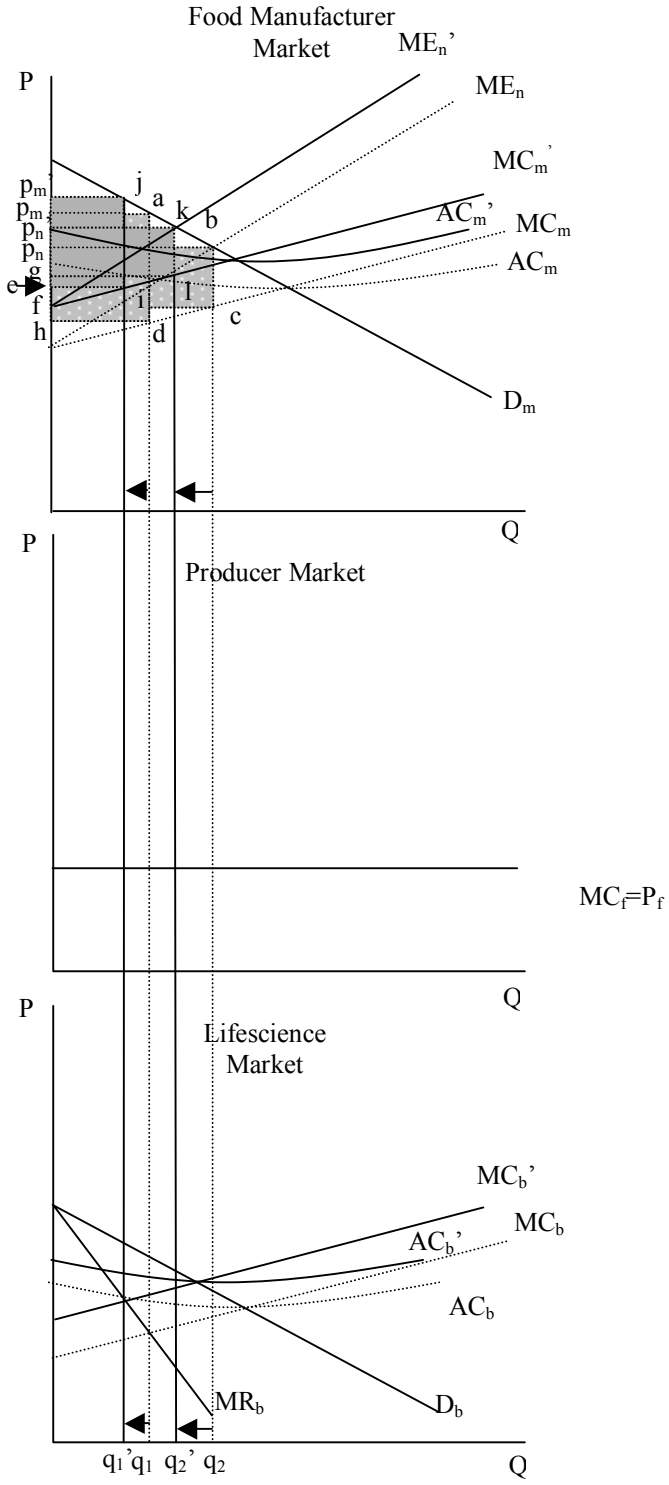

Figure 3.8. The supply chain with increased transaction costs

Figure 3.8 shows the supply chain situation, but to get a better notion of the change in rents available as a result of the increase in costs, the food manufacturer's graph will be examined separately. Figure 3.9 shows this situation. As a result of the increase in transaction costs, the shift in marginal cost to the lifescience firm is passed along to the food manufacturer. This is shown in Figure 3.9 as a shift from MC_m to MC_m'. As a result of this shift, the marginal expenditure of the lifescience firm shifts from ME_n to ME_n'. This increase in transaction costs also causes an increase in the average cost that the food manufacturer faces from AC_m to AC_m'.

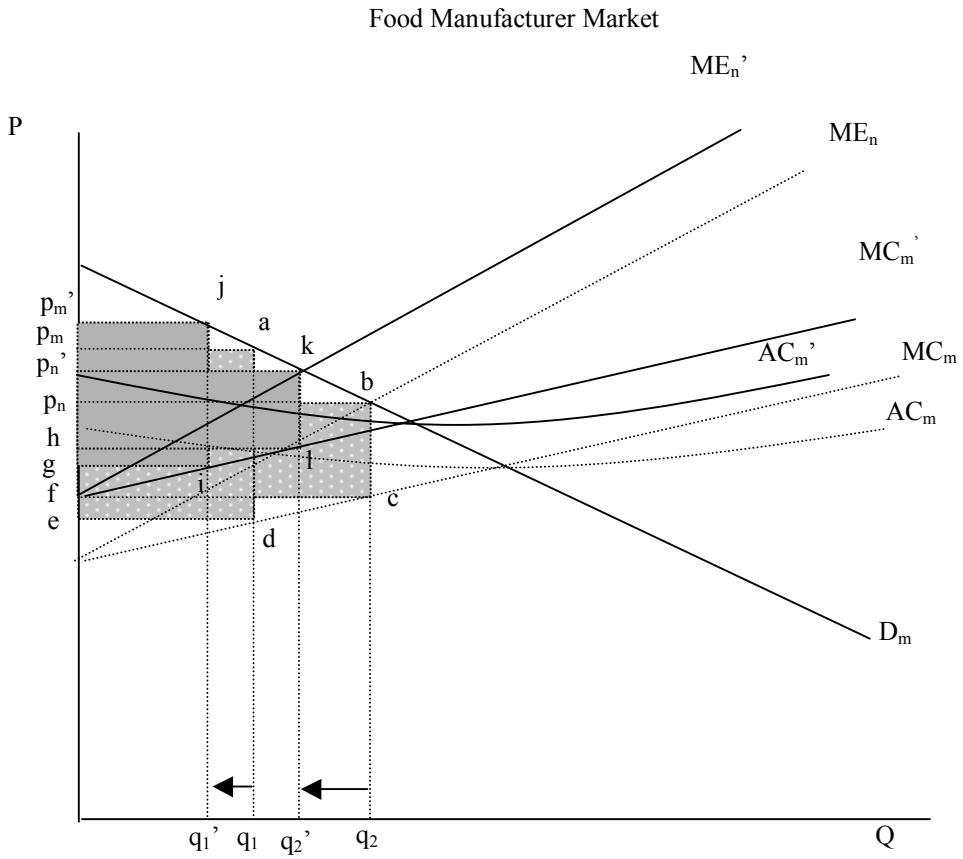

Figure 3.9. The change in rents resulting from an increase in transaction costs

As a result of the shift in marginal costs, the optimal quantities for both the monopolist lifescience firm and the monopsonist food manufacturer decreases. The available rents to be distributed throughout the supply chain decrease as a result of the shift in marginal cost. The new optimal rent to be distributed through the supply chain for the monopoly lifescience firm is area p_m'jig, which is smaller than the original monopoly rents equal to area $p_m$ade. The food manufacturer will want to bargain towards the monopsony solution, in which the new rent becomes area p_n'klh which is also smaller than the original monopsony rent equal to area $p_n$bcf. To distinguish between the two areas they have been shaded differently. The situation resulting from the increase in marginal cost is in solid grey on top of the original situation, which is a lighter and patterned grey. The end solution in terms of the available rents, prices and quantities will depend on the relative bargaining power of the monopoly lifescience firm and the monopsony food manufacturing firm.

These increases in marginal costs mean that the size of the rents to negotiate over will be smaller. The rents are necessary to pay for the research and development costs that the lifescience firm must endure to bring the product to market. They must also cover the costs of developing a new product for the food manufacturing firm. If the transaction costs involved in attaining licenses increase it could lead to the development of GM functional foods becoming infeasible. Another important consideration is the consumer demand as shown in Section 3.3. Any small decrease in demand could cause a large change in the rents available for distribution throughout the supply chain.

The actual cost of the license is also important to consider. This cost would not likely affect the marginal cost, but instead would be a fixed cost to the lifescience firm.

This would increase the average total costs. Although the figures in this chapter do not explicitly model these license costs, they are also important to consider. If the cost of the license(s) in addition to the other research and development costs become higher than the rent distributed to the lifescience firm, the GM functional food research will become unfeasible.

There could be additional problems to consider besides the increase in marginal costs as a result of an increased number of negotiations for licenses. There could be a case of multiple bilateral monopoly negotiations. Recall that a single bilateral monopoly reduces the amount of rent to be distributed from the optimal amount (Williamson, 1971). If this level of rent is further reduced from the optimal amount with every additional bilateral monopoly negotiation, the rent available for distribution could become too small to cover the fixed costs of purchasing the license(s) and research and development costs. The rent distribution with multiple bilateral monopoly negotiations could be an additional obstacle to the commercial development of GM functional foods. The rent must be distributed to cover fixed costs, and the market must cover marginal costs in order for there to be incentives for investment at any level of the supply chain for GM functional foods.

3.6 Summary

This chapter provides an in depth analysis of the three challenges that could cause a set back to the commercialization of GM functional foods. First, the vertical market is overviewed, and the challenges of a bilateral monopoly explained. It is not possible to determine a solution for rent distribution exactly because it depends on the relative

bargaining strength of the parties involved. If another monopoly were added to this model in the form of an owner of intellectual property, it would further complicate the problem. Realistically, there are multiple owners of intellectual property, and each negotiation is a bilateral monopoly meaning determining a solution is difficult.The analysis shows that there are a number of price and quantity combinations possible, as well as rent that must be distributed between the lifescience and food manufacturing firms through bargaining.

Next, the first of the three factors delaying commercialization is discussed. The effect of government uncertainty on the expected profits of the lifescience firm is modelled. Considering the fact that in Canada, there are no formal functional food regulations in place, a firm deciding to invest into research and development will assess the current regulatory framework, and proposed regulatory changes in the future. Since the firm (lifescience, food manufacturer or both) developing the GM functional food will not seek regulatory approval for close to a decade, the firm will respond to uncertainty and adjust the expected probability success accordingly. The probability of success, when multiplied by the projected profits will give the firm an idea of the expected profits from an innovation. As the uncertainty increases the probability of success decreases, which lowers expected profits. The firm might then choose to invest in less risky areas causing a set back in the development and commercialization of GM functional foods.

The heterogeneous consumer model shows how the brand image, price and efficacy of the functional food will affect its demand. The key to success in this market is to provide a highly demanded functional characteristic that satisfies the health benefit it promises. It is also important to balance the brand image with price. If the premium for the GM functional food is too high, it will lose market share. If bad press surfaces or

consumer groups strike back against the brand as a whole, the firm could be a lot worse off in terms of market share than if they had not introduced the new functional food.

Following up on the heterogeneous consumer model in Section 3.3, simulation analysis is performed. The model shows the effect of changes in the base utility, price and discount parameter of GM functional tomato paste on the market shares of the functional tomato paste, the conventional tomato paste under the same national brand and the substitute under the store's own-brand. Two scenarios are used to form a base scenario from which the shocks are introduced to the system. The first scenario starts with each firm holding a 50% market share prior to the introduction of the GM functional tomato paste, while in the second scenario the national branded conventional tomato paste starts with a 70% market share and the substitute has 30%. In each case a base situation is set up with the GM functional food holding a 10% market share. While both scenarios prove to be sensitive to all shocks introduced, the second scenario is relatively more sensitive. This could be viewed as the level of risk in each scenario. If firms start out with the second scenario they will want to include more risk into their projections for market share and profitability.

The final section discusses the transaction cost issues relating to gaining access to intellectual property. It begins with the situation shown in Figure 3.1 and shows the effect that an increase in the information, negotiation and monitoring costs can have on the amount of rents available for distribution in the supply chain. It shows that if the increase in transaction costs causes a shift up in the marginal and average costs, the amount of rent available decreases. This concerns the lifescience firm because they have to pay for their research, development and licensing costs through the rent that they receive. It also

concerns the food manufacturer because they must pay for any facility upgrades and product development that is necessary to commercialize the functional food.

The sections can be informally tied together to intuitively explain the true challenge to the commercialization of GM functional foods. The simulation analysis shows the sensitivity of market share caused by shocks to the base utility, price and discount parameter from the model developed in Section 3.3. If the government uncertainty model is considered in unison with this model, the expected market share would be equal to the market share calculated in the model multiplied by the probability of success. This means the market share becomes smaller. As the regulatory uncertainty increases, the probability of success and in turn the expected market share decreases.

The expected market share is directly correlated to demand.[18] Changes to the demand will have a direct impact on the rent to be distributed through the supply chain. If the marginal cost increases because of high transaction costs, it causes a decrease in the available rent. If this is combined with a drop in expected market share, the rent could become small enough that the lifescience firm and the food manufacturer do not cover their research and development costs. This would make investment into the commercialization of the GM functional food infeasible.

The next chapter develops three cases that will explain practical examples of success and failure with food innovations. While there are no GM functional foods to examine, the case studies assessed give similar experiences from which lessons can be learned. The case studies attempt to analyse the situations with respect to supply chain relationships, and how the supply chains functioned or failed.

[18] The demand for the GM functional food would be equal to the total demand for the products in the market multiplied by the market share of the GM functional food.

CHAPTER FOUR

AN EXAMINATION OF THREE CASES

4.1 Introduction

At the present time, there are no commercially available GM functional foods to examine in order to study the issues affecting the industry. For this reason, case studies of alternative products are used to learn lessons from past experiences from which useful inferences can be made. Three cases are examined. The first is a GM tomato product that was made into puree and sold in the UK. Next, a GM potato product is examined. Finally, Nexera canola is studied. Nexera is a conventionally-bred Canadian variety with functional traits. Links between these cases and the problems delaying the commercial introduction of GM functional foods are drawn.

4.2 The case of GM Californian Tomatoes

An interesting case to examine in order to learn from past experience is the GM tomato. The first GM food on the market was the Flavr Savr™ Tomato, which was introduced by the firm Calgene on May 21, 1994 (Bruening and Lyons, 2000). Calgene was later purchased by Monsanto. This tomato was aimed at the fresh produce market. It was modified using transgenics, so that the softening of the outer cell walls was delayed, leading to a delayed ripening of the tomato. The results were two-fold: first, the tomatoes

could be picked at a riper stage, meaning more flavour and elimination of the use of ethylene to induce ripening. Second, the tomatoes looked riper on the store shelf and had a longer lifespan after purchase.

Following the introduction of the Flavr Savr™ tomato, Zeneca, a Swiss-based firm whose agribusiness operation merged with the agribusiness operation of Novartis in 2000 to form Syngenta, introduced a GM tomato to California tomato growers in February, 1996 (NCBE, 2005a). The main difference between this tomato and the Flavr Savr™ tomato was that the Zeneca version was designed primarily to be processed into tomato puree, destined for markets in the UK. A Zeneca – University of Nottingham collaboration identified the polygalacturanase gene (pTOM6) responsible for the structure of the cell wall during ripening. However, this is the same process that was patented by Calgene for the Flavr Savr™ tomato. The two firms agreed that because they were focused on different end-uses, they could split the market. Calgene would continue to focus on fresh tomatoes, while Zeneca would participate in the processed market (Harvey, 1999).

The delayed-ripening technology proved to be well-suited to the production of processed tomatoes. The GM tomatoes produced a processed tomato product with improved flavour and high viscosity (Harvey, 1999). This is in contrast to the majority of GM products introduced to date, that have no direct consumption benefit to the consumer. Research also focused on boosting the level of lycopene (a functional food component) present in the tomatoes. However, this was not part of the final commercialized product. It was a difficult balance to enhance the levels of lycopene while keeping it 'bio-available' to consumers, so that their bodies could absorb the

functional nutrients. Also, volunteers involved in taste-testing were asked to eat a whole can of lycopene-enhanced puree, which was not a positive experience. The volunteers preferred lycopene-enhanced paste that was cooked similar to pizza or pasta sauces (Harvey, 1999).

The tomato puree was a test product for Zeneca. Zeneca was going to monitor the success of the tomato puree to make decisions on producing future tomato products such as ketchup. Several retailers were approached with offers to sell GM tomato puree (Combes, 2005). Safeway and Sainsbury's took the offer from Zeneca and marketed the puree under their respective private labels. Private labels comprise 75% of shelf space in UK retailers. The puree was boldly labelled as "made with genetically modified tomatoes" on the front of the label (NCBE, 2005).

The supply chain was organised similar to conventional tomato puree. The GM tomatoes were segregated for specific use for the two private label GM tomato purees. Zeneca sold the seed to the growers. Because the GM tomato puree was a test product, Zeneca was more concerned in observing consumer reaction than making a profit. The main efficiency gain for the GM tomato puree occurred because the normal loss of 40% of the tomato juice did not occur during transportation. This gain was realized by the growers and processor, and was partially passed to the consumer in the form of a lower price. The retailer made the same margin on the GM tomato puree as they did on other tomato purees (Combes, 2005). This coordination between Zeneca, the processor Hunt Weston and Sainsbury's/Safeway was cited as an efficient supply chain (Chiesa and Toletti, 2004; Harvey, 1999). This relationship worked smoothly, even though the level

of vertical coordination in the form of monitoring by Safeway and Sainsbury's was higher than Hunt Weston was accustomed to.

The marketing strategy used for the GM tomato puree was successful. The day of the introduction of the GM tomato puree, positive news coverage reached 22 million British viewers. Because it was a test product, GM tomato puree was not sold in all Safeway and Sainsbury's locations. Target markets included locations with TV stations and locations close to universities. Students were targeted because the packaging of the GM tomato puree was relatively convenient for students (Combes, 2005). By the end of 1997, Safeway reported selling 750,000 cans, while Sainsbury's had sold over 1 million cans (Soil Association, 2003; Combes, 1997 cited in Harvey, 1999). At this time, the GM tomato puree was outselling conventional puree when they were competing in the same store. The two were always sold together in the retail environment for ease of comparison for the consumer. Another factor that contributed to the success of the GM tomato puree was the price advantage. The GM product carried the same retail price, but the package was 20% larger.

Opposition to biotechnology has existed almost as long as scientists have been doing research using its methods. This opposition was the reason that Zeneca sought multiple retailers with which to coordinate. Multiple firms allowed for cooperation and spread the risk to Zeneca. The Institute of Grocery Distribution[19], also got involved to make sure that there was consistency in the labelling of the goods (Harvey, 1999).

[19] The Institute of Grocery Distribution (IGD) is a charitable organisation based in England and Wales that is funded through activities (conferences, commissioned publications, briefings, etc.) of IGD Services Ltd. It provides services to all levels of the food supply chain. The Board of Trustees is composed of executives from several European food manufacturers.

With a smoothly operating supply chain, and strong demand from consumers one would expect that this would be a success story. However, the product was removed from store shelves by the end of 1999. This was partially as a result of competing retailers, specifically Marks and Spencer, making public statements regarding the removal of GM foods from their private labelled product offering (NCBE, 2005b). It was also stated that the demand for the tomato puree had begun to subside following a research study by Arpad Pusztai, which appeared to show negative health effects of consuming GM foods on rats (NCBE, 2005b). However, another contributing factor to less sales of the GM tomato puree was that supplies had been exhausted from high demand. This meant that the GM tomato puree was not available to consumers anymore (Combes, 2005).

4.2.1 Links between the GM Californian Tomato Puree and theory

In order for the GM tomato puree to succeed in the long run in the UK it would have to be grown in the EU. The transportation costs involved in shipping tomato puree from California were relatively high. Most tomatoes in the UK are imported from Spain and Italy. Regulatory approval for growth of the GM tomatoes in these countries was initially delayed and finally refused. This was a factor in the failure of the GM tomato puree (Combes, 2005). Not only did the regulatory uncertainty limit the expected profit, but the actual profit from the GM tomato puree was reduced because of increase transportation costs involved in shipping the tomato paste from California.

The fact that this product was a success prior to its removal confirms that the success of a single product is not necessarily sufficient for it to remain on the market. The removal of the GM Californian Tomato Puree from Safeway and Sainsbury store shelves

allowed the firms to make the claim that their private labelled products were GM-free. This case shows that brand equity is an important consideration. Even though the product was initially successful, the value of keeping the product was less than the value to the retailers' brand equity of making a GM-free claim. With sustained production, the demand for the GM tomato puree could have stayed high. However, the overall market share or profits of the grocery retailers supplying the GM tomato puree might have fallen as a result of not being able to make the competitive claim that their private label products were GM-free.

It is difficult to link intellectual property issues to this case. The Zeneca tomato was able to avoid licensing costs from Calgene because of an agreement to target different markets. Also, there was only one key gene (pTOM6) compared to a GM functional food which could have several.

This product had improved quality and a lower price, and still failed. GM functional foods will likely be sold at a premium because of additional supply chain costs, such as the cost of increased identity preservation and transaction costs involved in gaining access to intellectual property. If a product with a large price discount cannot succeed, it suggests that a GM product sold at a premium could also fail.

4.3 The case of the NatureMark NewLeaf Potato

In 1995 a potato seed company called NatureMark, which was a subsidiary of Monsanto, introduced a transgenic potato in Canada and the US that enabled producers to use fewer applications of pesticides. Pesticide use is necessary in potato production to protect against a variety of pests including weeds, insects and disease. Potato production

is high-risk and production costs normally exceed $1000(US)/acre. The onset of a pest infestation can double or triple the production costs (Thorton, 2003).

The potato was viewed as an ideal candidate to be altered using biotechnology, because traditional breeding is especially time consuming in potatoes (Thorton, 2003). The first NewLeaf potato contained a gene inserted in the potato so that it exhibited resistance to the Colorado potato beetle. This was followed a couple years later by inserting a different gene that made the potato resistant to the potato leafroll virus (Thomas et al., 1997). The combination of these two pests accounted for 80% of the pesticide applications made by potato growers in the US (Thorton, 2003). Overall, three types of NewLeaf potatoes were introduced: NL10 was resistant to the Colorado potato beetle, NL20 was resistant to the Colorado potato beetle, and the potato virus Y and NL30 was resistant to the Colorado potato beetle and the potato leafroll virus. All of these varieties were fully approved in Canada and the US (NatureMark Potatoes, 2002).

Four varieties of potatoes were chosen to insert the NewLeaf genes into. The NL10 type was available in Russet Burbank, Atlantic and Superior varieties. The NL20 was available in the Russet Burbank and Shepody varieties, and the NL30 was available in the Russet Burbank variety (NatureMark Potatoes, 2002). These varieties had different uses depending on the variety. The Russet Burbank and Shepody are used for processing potato chips. The Atlantic and Superior varieties are marketed to the potato chip processors, while all four varieties can also be sold fresh for boiling (CFIA, 2005).

Coffin (2005) stated that viral resistance in the NewLeaf potatoes was especially important in Prince Edward Island (P.E.I.), where the incidence of infection was high. In field trials performed throughout the lifespan of the product, the NewLeaf varieties were

exposed to high levels of viral infections along-side conventional Russet Burbank potatoes. The Russet Burbank potatoes showed up to a 100% infection rate, while researchers could not find signs of infection in the NewLeaf varieties.

Growers contracted their production to two main processors in Canada, McCain Foods Ltd. and Cavendish Farms. In the US, the potatoes were also contracted to J.R. Simplot Company. The NewLeaf potatoes were not segregated in the supply chain. The main factor of concern to processors was the variety (i.e. Russet Burbank, Atlantic, Shepody, and Superior). The NewLeaf potatoes were not segregated, so it was not possible to sell processed potatoes as GM-free. Major buyers from these two processors were McDonald's and Burger King. Other major buyers of processing potatoes are Proctor and Gamble who make Pringles and PepsiCo Inc. who make Frito-Lay potato chips. A specific set of supply chain relationships arose for those potatoes.

4.3.1 The supply chain structure

Monsanto was the furthest upstream member of the supply chain, operating NatureMark as a unit devoted to potato breeding within Monsanto. In contrast to other types of agricultural supply chains, there are no seed companies in the potato industry. Monsanto dealt with this problem by searching the potato-growing regions and finding successful commercial potato growers to supply seed potatoes. Monsanto contacted these growers, and designated them as authorized to grow NewLeaf potatoes to sell as seed (Stark, 2005).

The seed growers grew the seed and sold it to other commercial potato growers. The commercial potato growers were required to sign licenses in order to purchase the

seed from the authorized seed grower. This license was in the form of a technology use agreement (TUA), similar to other GM crops that Monsanto sells.[20] Once the TUA was signed, the seed grower would send it to Monsanto. Monsanto would then invoice the commercial grower for a fee required to use the GM technology (Stark, 2005).

From that point on, the supply chain operated in basically the same manner as a conventional Russet Burbank potato. The grower is coordinated with the food processor. The contract specifies the price, variety and delivery date(s). The price of potatoes is negotiated at the time of contracting. Price is flexible and dependent on the applicable costs of production that the growers face (Coffin, 2005).

The processor then contracts to sell the processed potatoes to several different outlets. Cavendish Farms sells French fries to three groups of customers: (1) quick service restaurants (Burger King, Wendy's and Kentucky Fried Chicken), (2) grocery stores, and (3) food service firms in hospitals and schools (Coffin, 2005).

The potato processors in North America are highly competitive because there is a large amount of over-capacity in the industry. For this reason, if a processor wishes to become a supplier for a customer, they are in a difficult bargaining position. When this fact is combined with the negotiation to determine prices with growers, the processor is usually faced with a low processing margin.

There was an agreement between Monsanto and Cavendish Farms that was unique to these two parties (the other potato processors were not involved). Cavendish Farms has a fertilizer division that works with growers on agronomic issues. Monsanto

[20] The TUA is an agreement by the grower that they will sell all the production that they grow from the seed, and not use any for re-seeding (Stark, 2005).

arranged a service agreement with the fertilizer division to provide technical support to growers of NewLeaf potatoes.

Cavendish Farms, which processes potatoes into French fries, was a major buyer of NewLeaf potatoes in Canada. Of the small amount of NewLeaf contracted in P.E.I, Cavendish farms had 7,000 acres contracted at the peak of production (Coffin, 2005). This was approximately 6% of total potato production in P.E.I. which was 113,000 acres in 1999 (CHASS, 2005a). The NewLeaf potato was a product that Cavendish Farms was impressed with because of the effect it had on the quality of potatoes, due to the decrease in viral infection. It was also a product that, if adopted at a higher rate, would have led to more certainty in the production level of potatoes as a result of not being vulnerable to disease outbreaks.

In 1996, the acreage of NewLeaf Potatoes was 10,000 acres in the US, which increased to 50,000 acres by 1999 (Killman, 2000). This was still a relatively small proportion compared to the overall acreage of 1.3 million acres potatoes planted annually in the US. This small percentage is somewhat surprising given that Gianessi et al. (2002) calculated that if producers in Idaho, Oregon and Washington had planted the NewLeaf potato with Colorado potato beetle and potato virus in the 2001 season they could have benefited by $58 million and avoided spraying 1.45 million pounds of pesticide on 621,000 acres.

One of the main problems with the NewLeaf potatoes stemmed from the fact that there was no strategy in place for segregation. This meant that if a customer of one of the processors wished to purchase non-GM potatoes, the processor could not comply unless it only dealt with producers who did not grow NewLeaf Varieties. There was no financial

incentive for the processors to put resources into methods of determining whether or not potatoes were GM (Thorton, 2003). This was because there was no easy method to determine whether a potato contained GM DNA. An Elisa test is one method used to analyse proteins in a substance to determine the existence of GM DNA, but it is both costly and time consuming. Random tests conducted by the New Brunswick provincial government in conjunction with McCain Foods, showed that there were potatoes delivered that were supposed to be non-GM that contained the GM DNA. The conclusion was that growers were mixing the varieties together (Coffin, 2005). Given that there was no requirement to segregate, there was no real violation. If the Elisa test was not performed, there would have been no way to determine that the potatoes were different.

Cavendish Farms was an exception, because in their contracts with growers they specified the variety grown. They had the capability to call for delivery of GM potatoes at separate delivery times, but generally did not (Coffin, 2005).

4.3.2 The end of commercialization

Major changes started to occur in 1999 when McDonald's Corporation, reacting to increasingly negative consumer sentiment towards GM foods, instructed its suppliers to quit using GM potatoes (Killman, 2000). In reaction to McDonald's decision, Burger King, Wendy's, Proctor and Gamble (Pringles) and PepsiCo (Frito-Lay) were quick to follow with similar directives to their suppliers. The processors reacted to this news by instructing producers to stop growing the GM potatoes. As a result of the processors refusal to process GM potatoes, Monsanto had little choice but to stop selling the NatureMark NewLeaf Potatoes in 2001 (Thorton, 2003).

This case shows that in order to protect their brand image, firms like McDonald's forced their suppliers to process only non-GM potatoes, so that they could state they were GM-free. Once McDonald's made the claim, then competitors followed to avoid losing market share over the issue. The aggregate benefits of the NewLeaf potato were relatively minor. This is because the proportion of total potato production devoted to the NewLeaf potato was small. The potential benefits would have possibly been larger had the NewLeaf potato been adopted at a higher rate. The improved quality and more consistent yield were advantages that led to gains to the individual grower, and in turn the processor. However, the likely reason that firms such as McDonald's instructed suppliers to stop purchasing NewLeaf varieties was that the benefits passed to them were not high enough to justify taking the image risks associated with selling GM foods.

Potato producers did not adopt the technology very quickly; the maximum adoption rate in the US was just under 4%, while in P.E.I. it was 5%. Contrast this to soybeans in the US, which were grown under limited quantities in 1996, expanded to 17% of acreage in 1997, 56% by 1999 and 68% by 2001 (Fernandez-Cornejo and McBride, 2002). Although the adoption rate of NewLeaf potatoes was fast compared to other previous new potato varieties (Thorton, 2003), it was very slow compared to GM soybeans. There were a couple of potential factors that contributed to this issue. First, the TUA that the growers signed required them to plant varieties non-resistant to insects as buffers around areas where resistant varieties were planted. This was an attempt to reduce the growth of resistant insects. Second, a new pesticide called Imidacloprid (Admire brand by Bayer) was introduced at the same time as the NewLeaf potato (Stark, 2005). This pesticide offered producers an effective option against the Colorado potato beetle

relative to past pesticides (Thorton, 2003). However, a third explanation could be that the costs associated with gaining access to the technology were high enough that there was little incentive to switch. Unlike for soybeans, Monsanto had fewer acres to recoup the large costs associated with developing a new plant. Also, it takes years to build up the seed-stock of potatoes to a level where significant acres can be seeded (Thorton, 2003).

The fact that the NewLeaf potato was not on the market long enough to allow for more complete adoption meant that the percentage of US potato production devoted to NewLeaf potatoes was small. As a result, the increase in supply from adoption of the NewLeaf varieties was not high enough to cause a reduction in the price of potatoes. However, the potato processors were optimistic about the future potential of the NewLeaf varieties. With a higher adoption rate of the NewLeaf varieties, the level of certainty with respect to quality[21], price and supply in the market could potentially have been higher. This increased certainty would have led to more economic benefits to be passed down the supply chain. With the low adoption rate, the benefits to be passed along the supply chain were small.

If the NewLeaf potatoes were adopted at a higher rate, the processors would have passed the higher quality of the NewLeaf potato through to their customers in the form of higher quality French fries and potato chips. However, at the adoption rate that existed, the potential quality improvements must not have been high enough to compensate for the increased brand risk. For this reason, McDonald's demanded the processors they dealt with sell them only non-GM potatoes. Their competitors and other large buyers of processed potatoes followed.

[21] The quality of the NewLeaf varieties with viral resistance was higher in areas where there was disease problems, because they showed no signs of the disease (Coffin, 2005).

The NewLeaf potato was a part of a broad product offering by Monsanto at the time. There was a problem with the NewLeaf potato because it required a completely separate agronomic support system and staff than what was used by crops like corn and soybeans. This lack of synergy meant that there were a lot of costs involved with providing the necessary service for growers of NewLeaf potatoes. Initially Monsanto entertained offers to sell the NatureMark unit, but did not receive any offers that they thought justified selling it. Monsanto then decided to make NatureMark inactive, but have not dismissed the possibility of reintroducing it in the future (Stark, 2005).

The reaction to the NewLeaf potato has had a lasting effect on the parties involved. Monsanto is now starting to recognize that the reaction of the grocery stores and restaurants must be considered. They recognize that consumers identify what they want through the brands they consume (Stark, 2005). The processors are also concerned with the effect that the introduction of a new product will have on their brand image (Coffin, 2005).

The key supply chain issue with regards to the NewLeaf potato was the lack of segregation of GM from non-GM potatoes. The processors decided to call for an end to the production of the NewLeaf potato rather than segregation. One of the reasons was that the benefits that the potatoes offered may not have been high enough to compensate for the extra costs of segregation. As explained earlier, the potato processing industry was very competitive. The extra cost of segregation might have been a direct loss to the processors because they may have been unable to recover these costs from either the growers or their customers.

This case offers an example of a product with superior agronomics that also had the potential to offer a higher quality end product as a result of a lower incidence of disease. However, this potential benefit was not enough to compensate the downstream purchasers of the processed potatoes for the risk of consumer backlash as a result of the NewLeaf potato being GM.

This case study could be analysed as a situation similar to the bilateral monopoly modelled in chapter four. In this case, the monopoly would be Monsanto. There is not monopsony, but the quick service restaurants (i.e. McDonald's and Burger King) could be considered an oligopsony. Even though there was no agreement between Monsanto and the quick service restaurants, the rents collected by the quick service restaurants would be divided throughout the supply chain. After Monsanto collected royalties from the sales of NewLeaf seed, the remaining rent may not have been enough to compensate the quick service restaurants for the risk they felt they were exposed to by selling GM potatoes. For this reason they felt it was in their best interest to purchase only non-GM potatoes.

4.3.3 Links from the NewLeaf potato to theory

There was some regulatory uncertainty that played a role in the removal of the NewLeaf potato from the market. Authorities in Japan found that a shipment of potatoes carried the virus-resistant gene. This gene had been previously approved as being safe in Japan. However, Japan had put a regulation in place that prohibited the shipment of those potatoes without communicating this to the exporters. As a result of the new regulation, the shipment of potatoes was recalled. Because of the lack of segregation in the supply

chain, the continued growing of NewLeaf potatoes would have meant the loss of the Japanese market. This was an additional reason for pressure to discontinue growing the NewLeaf potatoes (Stark, 2005).

The NewLeaf potato was not segregated, so it is difficult to draw a direct link between the heterogeneous consumer model discussed in chapter 3 and this case. One of the potential reasons processed potato buyers such as McDonald's demanded that processors sell them non-GM potatoes was that they may have been concerned with losing market share in general. This in turn would have had an effect on their brand capital.

In some cases, the NewLeaf potatoes had two key pieces of intellectual property (Colorado potato beetle resistance and potato leafroll/potato Y virus resistance). However, it does not appear that access to intellectual property was a large problem. The only problem could be that there was not enough rent gained through the agronomic benefit to compensate Monsanto for its research and development costs, the grower, the processors and the processed potato buyers. The hypothesis would be that the processed potato buyers did not receive a large enough portion of the rent to compensate them for the increased consumer and branding risk resulting from the fact that he potato was GM.

4.4 The case of Nexera Canola

Nexera canola is a product that was developed by Dow AgroSciences, and is an example of a functional food derived from conventional breeding. Nexera canola is used to produce Natreon canola oil. In contrast to other vegetable oils, it is naturally stable. Therefore it does not require hydrogenation, which means virtually no trans-fats are

present. It is also low in saturated fats. The oil has a higher level of oleic and a lower level of linoleic acids than conventional canola, which is the reason that the oil is naturally stable (Malla et al., 2005). It is estimated that 20,000 deaths per year in the US could be attributable to trans-fats (Harvard School of Public Health, 2004, Cited by Dow AgroSciences, 2004).

As a result of these health concerns, the US is introducing new trans-fat labelling regulations in 2006. Canada will have similar regulations in place by December 2005 for large food manufacturers, and for all food manufacturers by 2007 (Malla et al., 2005). As a result, Dow AgroSciences expects demand for Nexera canola to increase. At the present time the majority of packaged processed foods contain hydrogenated oils, which lead to the formation of trans-fats (Dow AgroSciences, 2003).

The Nexera case is an interesting one to examine as a benchmark for how the supply chain relationships could be expected to develop for GM functional foods. A major difference is that Nexera was developed through conventional methods. All of the production, transportation and handling and processing occur through an identity preserved system. Due to the special traits that this canola exhibits, it cannot be commingled with other canola. Canola producers sign an identity preserved production contract when they buy their seed, which offers them a premium on a basis contract compared to regular canola. At the present time, Louis Dreyfus is offering a $34/tonne premium on the November 2005 basis from its Lyalta, Alberta location (Louis Dreyfus Ltd., 2005). The contract states a delivery period. The canola crusher is free to choose a date within this period to command delivery. The crop is then picked up from the producer's yard and delivered directly to the crusher. The crusher must clean out the

facility and have a specialty crush period where only the Nexera canola is crushed. In Canada, the crusher for Nexera canola is Canbra Foods Ltd., a subsidiary of James Richardson International located in Lethbridge, Alberta. There are two grain companies involved in the formation of contracts with producers, Pioneer Grain Company Ltd. (subsidiary of James Richardson International) and Louis Dreyfus Canada Ltd.

Nexera canola is currently grown in western Canada, where it represented 3.5% of acreage in 2002 (Phillips and Smyth, 2003; CHASS, 2005b) and estimated to be approximately 5% of canola acreage in 2005 (Zacharias, 2005, cited in Malla et al., 2005). About half of the Natreon oil processed from Nexera canola is sold to North American food service and food manufacturing industries (Malla et al., 2005). Interestingly the Nexera brand is not promoted in these locations. Currently no Natreon canola oil is sold directly to consumers at the retail level in Canada. The Natreon canola oil not sold in North America is sold in Japan (Malla et al., 2005).

This case shows that although there are extra vertical coordination costs involved in this supply chain as a result of the identity preservation, the product appears to be successful. The producer is compensated for their extra costs through a price premium. Also, other parties in the supply chain must endure extra costs when handling the specialty canola, and must be compensated as a result. This must be happening, as production of Nexera canola continues currently.

Also, the supply chain gives an example of a functioning bilateral monopoly. Dow AgroSciences is the sole provider of the Nexera Seed, while Canbra Foods Ltd. is the only crusher that processes the canola into oil. However, Cargill Limited produces

and markets InterMountain Canola which is also trans-fat free (Malla et al., 2005). This provides some competition in the supply chain.

Nexera canola targets an issue (trans-fats) that consumers are increasingly concerned about. The fact that regulators are also concerned about the effects of trans-fats has led to proposals to institute trans-fat labelling regulations. This is a positive regulatory development for those participating in the supply chain for Nexera canola. The fact that Nexera is not GM offers it an additional form of differentiation in the market, because the majority of canola produced in Canada is GM. For this reason, marketing Natreon canola oil does not have the same level of risks as a similar GM product, caused by consumer aversion and backlash against the brand. The fact that the benefits of Natreon canola are not promoted by the food service and food manufacturers in Canada is unusual because of these apparent benefits that the product provides.

4.4.1 Links from Nexera canola to theory

In the case of Nexera canola the government regulatory environment in North America will assist the product in its success in the next couple of years. Canada will have trans-fat labelling regulations in place by December 2005, while the US will have regulations in place in 2006 (Malla et al., 2005). To avoid labelling food with trans-fat labels, food manufacturers will search out oils like Nexera which contain little trans-fat. In this case the regulatory uncertainty is reduced because developers have the trans-fat labelling regulation as guidance. In contrast to aiming to make a nutritional claim, the Nexera/Natreon products avoid having to make a claim.

The consumer aversion and brand risk problems discussed in the theory section do not necessarily apply to Nexera canola because it is not developed through biotechnology. It is interesting that it is not promoted in North America under the Natreon brand, even though intuition would lead one to assume that this product would have a positive consumer image. A possible explanation could be that it is currently produced as a low percentage of total canola production. Natreon canola oil could not supply the entire market. If Natreon was promoted as healthy, it might gain market share, but the negative effect on the reputation of existing canola oil products could be more significant. Currently, consumers might not recognize that the oils are unhealthy. The introduction of a healthy alternative like branded Natreon might alert consumers to the unhealthy aspects of other canola oils, leading to a lower willingness to pay. This could lead to a net loss to the crusher.

The issues relating to access to intellectual property are not a major concern in this supply chain. Because biotechnology is not used in the development of Nexera canola, the intellectual property issues involved with biotechnology are not a factor. Also, Dow AgroSciences is the owner of the brand name, which eliminates the need to license the brand. The absence of these issues may be a contributing factor to the success of Nexera canola.

4.5 Summary

The case of the GM Californian tomato puree shows that food manufacturers and retailers will eliminate successful products in order to reduce the chance of consumer backlash towards their brand. This reaction to consumer aversion was echoed in the case

of the NewLeaf potato. In this case the benefits of higher quality potatoes that were exposed to fewer pesticides were not passed to buyers of processed potatoes. Restaurants like McDonald's wanted to make the statement that they did not use GM potatoes. This too is a significant case because of the long-term potential that the NewLeaf potato had to provide a higher quality, more consistent yield of potatoes. The result of more consistent yields would be less crop failures and a lower price of potatoes. Eventually, this could mean higher profits to the downstream firms. Considering that the buyers of processed potatoes have market power, it would be assumed that the profits would eventually be received by the firms like McDonald's. Despite this, they made the decision that a GM-free claim was more valuable to the company.

Finally, the Nexera canola case shows that a functional food with an identity preserved supply chain can be successful. It gives an indication of the possible supply chain structure for a GM functional food. However, the value of the case is limited by the fact that the problems associated with access to intellectual property do not exist to the same degree as can be expected in GM equivalents. Gaining access to intellectual property would be an additional cost to the supply chain that would have to be recovered by a consumer price premium.

The next chapter provides a discussion of the key issues examined in this thesis. It offers supply chain implications and examines potential products that could be expected to be developed as GM functional foods.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This chapter uses the literature reviewed in Chapter two, along with theoretical modelling performed in Chapter 3 to discuss the implications of the potential problems on the development of commercial GM functional foods. It also uses the information from the case studies examined in Chapter four that highlight some of the problems and positive lessons from past products. Finally, the discussion ties these factors together to make inferences regarding the potential structure of the supply chain for GM functional foods.

5.2 Implications of the three factors

Any one of these factors: government regulatory uncertainty, consumer aversion and branding risk, or access to intellectual property could cause a set back to the commercialization of a product. The fact that all three exist simultaneously in the supply chain for GM functional foods means that the potential for delayed commercialization in this industry is high. This section discusses the implications of each problem and then ties them together.

5.2.1 Government regulatory uncertainty

The first factor that was discussed was the regulatory uncertainty that exists with respect to biotechnology and functional foods. Evidence from Chapter two showed that this uncertainty has been a major barrier to the introduction of new functional foods. The implications of this regulatory uncertainty are shown in Chapter 3. The increased uncertainty will cause a decrease in the probability of research and development success (α)[22]. This means that the expected profit of investing in research and development decreases.

The ideal method to increase the value of α in this case would be to decrease the level of regulatory uncertainty. The firms involved in research and development of GM functional foods might find it in their best interest to lobby regulators to develop some clearer regulations with respect to the certification and allowable claims in functional foods. If there were specific regulations in place, the firms doing research would have a better idea of what type of products and claims they would be able to make and the requirements that they have in regards to proving a claim is legitimate.

Policymakers interested in promoting innovation in functional foods could contribute by administering regulations that provide clear guidance to industry stakeholders. If innovators could follow regulations stating allowable claims, and the requirements for approval of new claims, they could develop a research strategy to target those claims. Innovation could also be stimulated by introducing a regulatory process for approval of new functional foods. This approval process would not only offer innovators

[22] Recall that α ($\alpha \in [0,1]$) represents the estimated probability of research success in commercial development of a GM functional food in the model in section 3.2. As the level of government uncertainty increases the value of α decreases, leading to a lower expected profit.

a consistent regulatory method to follow for new introductions, but also some reassurance to consumers that these foods are considered safe[23].

At the international level, harmonization of regulations with respect to GM functional foods would lead to the highest rate of innovation. However, complete harmonization is a challenge because nations desire sovereignty when developing regulations, especially in foods. The optimal international regulations for GM functional foods would be based on generally accepted scientific studies. For example, if one country approved the functional food and its claim, approval in other countries could be made based on the scientific evidence from the first country. This would eliminate the repetition of scientific tests for regulatory approval in multiple countries.

5.2.2 Consumers and branding

The next problem that was discussed was consumer aversion to the technology and the branding problem. Within the highly concentrated food processing sector, the brand equity of the firms is important. When considering the introduction of GM functional foods as a part of their product offering, food manufacturers will consider the risk to their brand. Following the propositions by Cabral, the choice made by individual firms will depend on the current reputation of their firm, combined with the quality of the product they plan to introduce.

Chapter 3 showed that a GM functional food that was valued highly by consumers could have a beneficial effect on the firm as a whole. However, a food safety concern or recall of the GM functional food could have damaging effects on the brand equity of the

[23] The idea that the regulatory procedure can convey food safety to the consumer is mainly a North American concept. As was explained earlier in the thesis, many Europeans have a distrust of regulators.

firm. Food firms will have to weigh the benefits of introducing a new food with functional attributes against the risk that a negative consumer reaction could result in a backlash against the firm's entire product offering.

Lifescience firms investing in the research and development of GM functional foods should realize this *ex ante* and plan the products they develop accordingly. Unlike crops like soybeans, corn and canola that have been the main successes that the lifescience firms have experienced so far, the introduction of GM functional foods will require coordination with food processors.

Lifescience firms have learned that in order to have future success, they need to focus on developing products that target demands of food manufacturers and consumers (Stark, 2005). They have the ability to research new products with applications in the food sector. However, as a result of the time it takes to turn an idea into a commercialized product, the lifescience company cannot afford to invest in a fad (Stark, 2005). This is one reason why simply considering consumer preferences is not sufficient to predict the potential success of a product. The products developed will aim to target problems in a method that is sustainable. For example, a growing and constant problem is safe and healthy methods of targeting heart disease and obesity. Trendy diets, such as the Atkins diet, rise and fall but the core problem still remains. Researchers of GM functional foods will look to target these problems with sustainable products that are still able to satisfy consumers' tastes. It will then be up to the individual food manufacturers to decide whether the qualities the GM functional food brings forth are a worthwhile product with which to expand their brand.

5.2.3 The access to intellectual property problem

The final problem that was discussed was the potential for added costs while gaining access to the intellectual property necessary for the development of GM functional foods. The lifescience firm faces these costs while gaining licenses for access to the technologies. The necessity to gain access to the technologies means having to find information on the pieces of intellectual property that must be licensed and then negotiate the terms, conditions and cost of the license with other lifescience firms or basic technology providers.

Currently there are no institutions in place to standardize the exchange of these contracts. The contracts are negotiated ex post to initial research on a case-by-case basis. In the case of a potential GM functional food for which the developing firm requires access to several pieces of intellectual property, the resulting transaction costs could be high. In some cases the process could be held up if the firm holding the intellectual property wishes to retain exclusive access. In any case, the transaction costs associated with the negation process could increase the marginal costs in the supply chain, reducing the amount of rent available for distribution.

The solution to this problem is complicated, as there are a number of possible results because of the bilateral monopoly market structure between the upstream lifescience firm and the downstream food manufacturer. The solution will depend on the relative bargaining strength of the two parties. In order for the food manufacturer to have the incentive to invest, they will have to make at least as much from investing in GM functional foods as they could from investing into existing products. The lifescience firm

will have to cover its costs of research and development as well. Depending on the amount of available rents, there might not be a solution to meet these requirements.

5.2.4 Tying the factors together

If each of the preceding three factors alone appear to be capable of causing a set back to the commercialization of GM functional foods, when combined they are a severe hindrance. The market share of a product is directly correlated to the demand for that product. A change in the demand for a food causes the rent available for distribution throughout the supply chain to change accordingly. An increase in the uncertainty resulting from regulatory ambiguity, causes the expected demand to decrease. It follows that the expected rent for distribution throughout the supply chain to decrease. The food manufacturing firm must consider the risk involved with expanding their brand to include GM functional foods as a result. Section 3.4 showed the sensitivity to market share as a result of changes in the base utility that could be a measure of brand image. This type of sensitivity analysis could reveal to a food manufacturer the potential risks and benefits to the firm from shocks to the variables and parameters. When this demand risk is considered, the expected demand and in turn the expected rent available to distribute could decrease.

The demand challenge is then combined with the supply issues complicated by the added costs within the supply chain. When compared to a conventional food, the developers of GM functional foods will have to deal with increased transaction costs to attain access to intellectual property necessary to develop products. Also, there are potential increased coordination costs resulting from the need to have an identity

preserved supply chain to maintain the functional attribute in the GM functional food. The combination of these factors will have an effect on the marginal cost and in turn the amount of rent available for distribution.

The final factor to keep in mind is that the rent available to both the lifescience firm and the food manufacturer must be at least as good as the other opportunities available to them. If return from investment elsewhere is higher, there will be little investment in the development of GM functional foods.

Alternatively, the expected returns from investment in GM functional foods could be relatively high. The food manufacturers might predict that the introduction of health-promoting products could boost their brand image. Also, the lifescience firm could own the intellectual property necessary to develop the product and therefore face little to no cost in acquiring licenses. Finally, the agreement between the lifescience firm and the food manufacturer for processing could be simple, similar to the Nexera canola case study. In this case the firms involved might see a good opportunity to invest in GM functional foods.

5.3 Potential supply chain developments

This section presents possible supply chain structures that would facilitate negotiations between a lifescience firm and a food manufacturer and reduce transaction costs and uncertainty.

5.3.1 The market for intellectual property

The furthest upstream transaction in the supply chain for GM functional foods is the acquisition of licenses for intellectual property. As was mentioned in chapter two, there are no standardized institutions in place to reduce the impediments involved in gaining access to intellectual property. As a result, when the amount of intellectual property contained in a product increases, the transaction costs involved in gaining access to these technologies increases simultaneously. An independent institution such as a clearinghouse could offer a database of patented technologies and the owners, and provide a standard set of terms, conditions and basis for prices that would reduce the transaction costs involved in accessing this intellectual property.

The clearinghouse could offer those firms willing to sell licenses an opportunity to put them on the market. The clearinghouse would then act as an independent mediator allowing participants a forum to make agreements. The price would depend on the demand for specific pieces of intellectual property. For example, a valuable piece of intellectual property necessary for the development of several products would have a higher price than intellectual property with a use that is more specific for a single product. As was explained in chapter 2, many holders of intellectual property must sell licenses in order to generate revenue from them. These firms do not have the expertise to develop new seed, so holding exclusive access has no value to them. It is becoming common for firms to realize that licensing technology is more profitable than maintaining sole access.

If the patenting of genetic material continues, it could lead to a delay in the development of not only GM functional foods, but several other products using this

technology. Regulators might want to take the initiative to develop an intellectual property clearinghouse in order to address this problem. The clearinghouse might solve an institutional failure and lead to a higher rate of innovation of products containing a high level of intellectual property.

Firms holding patents that offer them a greater advantage if they keep sole access would simply not offer the intellectual property in the clearinghouse. If sole access is maintained for a piece of technology, it would not be available for licensing to other firms through the clearinghouse. Firms who know that they are using a piece of intellectual property that is not available for licensing on the clearinghouse will then look to use alternative methods of producing their product. However, if too many firms decide to maintain exclusive access, the amount of valuable intellectual property utilizing the clearinghouse could be small. In this case, technologies requiring access to these technologies will be held up.

The intellectual property clearinghouse could help to reduce the transaction costs associated with gaining access to intellectual property rights. However, the problem of multiple bilateral monopoly negotiations might not be avoided. If the problems associated with the distribution of rent exist the supply chain for GM functional foods, it will pose an obstacle that is more complicated to solve.

5.3.2 Vertical relationships

The supply chain for GM functional foods will be more complicated than for the majority of agricultural commodities produced. As a result of the functional trait that has been modified into the food, the supply chain will have to be set up to segregate the crop

from conventional relatives. This identity preserved supply chain will require coordination between all levels of the supply chain.

Furthest upstream, there will be a contract between the lifescience firm developing the GM functional food and the owners of intellectual property in the form of a license. The license will either be paid for through a lump sum payment, or through royalties. If the agreement calls for a lump sum payment, the relationship will include little monitoring. However, if the payment is in the form of royalties on each unit of production sold, the monitoring of payment, and in turn the level of coordination at this level of the supply chain will increase.

The next downstream level of the supply chain will consist of the relationship between the lifescience firm and the producer of the food. However, in this case the food manufacturing firm will also be involved in the contracting process. When the grower purchases the seed, they will have to sign an agreement to sell the seed to the specified food manufacturer within a contracted delivery period. Most likely, the grower will pay a premium for the seed. To create incentive for investment into the seed, the grower will receive a premium on the price they receive over the conventional equivalent.

After the grower has purchased the seed, there are several factors that must be considered. First, the party responsible for agronomic consulting must be specified. This is because the grower will need advice when growing the food, and providing the expertise will be a cost to whichever party provides the service. Second, the party involved in monitoring quality must be appointed. The grower will be interested in who provides the inputs and who to contact with problems.

All of the preceding factors are reasons why there will be close coordination between the lifescience firm and the food manufacturer. The food manufacturer will be concerned with the quality of food produced, including the existence of the functional attribute. The two sides will have to determine who will be involved in the monitoring of crop quality, as well as who will support the grower for agronomic advice. The two sides might also want to provide inputs to the grower as a method of ensuring that the crop is grown in an approved manner. Because of these factors, the two sides will have to have a relationship that allows for good communication.

There will likely be coordination between the food manufacturer and the lifescience firm from the early stages of the development of the product. This is because in order for the supply chain to succeed, the lifescience firm will benefit from the cooperation of a food manufacturer interested in adding a GM functional food to their product offering. It is likely too big of a risk for the lifescience firm to come up with an idea and hope that there will be an interested food manufacturer when it comes time to market it. For this reason, the agreement between the food manufacturer and the lifescience firm will take place early in the development phases. This was the case in the agreement between Zeneca and Safeway/Sainsbury's in the case of the GM tomato puree. Also, because of the extra transaction costs and research costs involved in the development of these products, the lifescience firm might allow more control to the food manufacturer if they invest directly in the process. For these reasons, it is unlikely that a simple marketing alliance between the lifescience firm and the food manufacturer would be feasible.

A generalization could be made of a hypothetical situation involving a relationship between a lifescience firm and food manufacturer for the production of a GM functional food. Recall the observations of Oxley (1997) in chapter two. In the case of observation (1), there would potentially be an agreement regarding a specific product (the GM functional food itself). There could be a single product offered through the agreement, or a multitude of uses for a raw material, so the possibilities for observation (2) are hard to predict. Most likely the transaction will take place over a wide geographic area, considering the level of international agricultural trade that currently exists for most products. Regarding observation (4), the parties probably are involved in few alliances between one another with other products. From this generalization it is apparent that there would be a strong tendency for more hierarchical relationships, or joint ventures within the supply chain for GM functional foods. Within the joint venture there could be good communication and the incentive to maximize joint profits which would simplify the bilateral bargaining solution. The joint venture would ensure the lifescience firm that the food manufacturer was interested in the product, and lower the risk of opportunistic behaviour at a later date. For the food manufacturer, the joint venture would give them the opportunity to have a stronger influence concerning the products that are produced. It might also give them the opportunity to ensure that they receive a tangible benefit from processing the GM functional foods.

Overall, the supply chain will be challenging and complicated. A joint venture between the lifescience firm and the food manufacturer could be an efficient mechanism for the supply chain to function; however, the food manufacturer might not want to enter a joint venture with a lifescience firm because of the wish to maintain their brand image.

Cooperation between the lifescience firm and the food manufacturer could be perceived as an added risk to the food manufacturer's brand image because of the negative image of the lifescience firms with some consumer and environmental groups.

The highest level of coordination between the lifescience firm and food manufacturer would be if the two firms merged to become one through vertical integration. Klein (1978) stated that the probability of vertical integration increases as the level of quasi-rents increase. Following this, the higher the expected rents available for distribution in the supply chain are the higher the probability for vertical integration. Intuitively, this would be because negotiating in a bilateral monopoly reduces the amount of rent available from the optimum. Williamson (1971) states that in cases where the bargaining costs become higher than the cost of integration, the firms would be expected to vertically integrate. In the case of GM functional foods, vertical integration would be an unlikely solution because each firm produces a number of different products that would not be more efficiently produced if the firms were combined. The result would likely be *diseconomies of scope* where it is more costly for a single firm to produce all the products, than if the two firms remain separate (Mansfield, 1996). As a result the management costs of operating an integrated lifescience/food manufacturing firm would likely be prohibitive.

In some cases, similar to that of the NewLeaf potato, the food retailing/restaurant sector should also be considered. The food manufacturers will have to take into consideration the reactions of the end-users before introducing a new product. Contracts will be made between the two sides for use. The difference between GM functional foods and the NewLeaf potato case is the fact that the GM functional food will be identity

preserved. The NewLeaf potato case showed that restaurants can influence the success or failure of a product through a simple decision to go GM-free. A similar scenario was shown in the GM tomato puree case and retailers making the decision that they wanted their own-branded products to be GM-free. This shows that the willingness of the restaurants and food retailers to use a product will directly influence its success.

5.4 Potential products

The potential products that could be introduced as GM functional foods deserve mention. It is valuable to note the GM products that have been successful in the past, along with the failures. The successful GM foods have been those that are manufactured and used as ingredients in other foods, rather than foods themselves. Examples of successes include soybeans, corn and canola. One of the main products extracted from these commodities is the oil, which is used in processed foods and for deep-frying. Also, especially in corn and soybeans, the seed is also used for animal feed. In both cases the food is not normally directly consumed.

The failures have been foods that are consumed directly. Examples are potatoes and tomatoes. These seem to be met with increased consumer backlash. Although there is value from adding functional attributes in these foods, they seem to have an increased risk to the parties involved. For this reason, it would be expected that the initial GM functional foods would not likely be foods that are consumed directly. Lifescience firms appear to be focussing their research on foods that are already available as GM varieties. Monsanto's decision to eliminate their NatureMark division to focus on their core

product offerings is a good example. Monsanto lists several functional products in the early development phase, all of which involve soybeans (Fraley, 2005).

5.5 Summary

This chapter begins by discussing the implications of the three factors that are used in this thesis to explain the potential for a set back to the commercialization of GM functional foods. On their own, government regulatory uncertainty, consumer aversion and brand image, or access to intellectual property could potentially cause a set back. When these factors are combined together, the potential for set back increases substantially.

Next, the supply chain structures that would facilitate efficient vertical relationships are discussed. Institutions such as an intellectual property clearinghouse might address a possible problem of missing institutions. Also, joint ventures between lifescience and food manufacturing firms could allow them to maximize joint profits. This could lead to the introduction of GM functional foods being mutually beneficial, which is necessary to the food manufacturer in order to expand their brand. Overall, there will be closer vertical coordination between all parties of the supply chain. In order for investment into functional foods to be justifiable for lifescience firms and food manufacturers, the extra costs in the supply chain will have to be covered by a price premium in the retail market.

Finally, information about past successes and failures in agricultural biotechnology are used to discuss potential products for future development. It seems that

a product like healthy oil soybeans might have the highest potential. Lifescience firms realize that because soybeans make up a relatively large proportion of crop production, the market for new varieties of soybeans is large compared to most other crops. Also, as a result of the high adoption of GM soybeans by producers, the food manufacturers have had little choice but to accept GM soybeans. GM soybeans are processed into oil that is not normally eaten on its own, and the GM protein does not remain in tact in the oil. As a result of these factors, the GM soybeans have been accepted more readily than GM potatoes or tomatoes, which were consumed directly and produced on a small scale.

The next chapter provides a summary of the thesis, as well as some final conclusions. It also provides an explanation of the short-comings of the thesis, combined with recommendations for further research.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

6.1 Summary

This thesis begins by stating that there is potential for a set back in the commercialization of GM functional foods. These foods, with additional health benefits beyond normal nutritional value, have been consistently referred to as the benefit that consumers will receive from biotechnology. However, government regulatory uncertainty, consumer aversion and brand image issues, and access to intellectual property were listed as factors that could potentially contribute to the delay.

The first objective was to identify the three factors and explain how they contribute to a potential for the set back to commercial development of GM functional foods. This was completed in chapter two. The second objective was to develop a theoretical model of each of the three factors. In chapter three, three separate models are used to show the effect that the factors have in the contribution to industry set backs. It also attempts to tie the factors together using a model of the vertical market. Finally, the third objective was to use the information and results from these two chapters, in combination with issues in the case studies in chapter four to make inferences regarding the potential supply chain structures. The addition of an intellectual property clearinghouse, and the formation of joint ventures between lifescience and food

manufacturing firms are specific examples of institutional and supply chain changes. Overall, the supply chain for GM functional foods would be expected to be more vertically coordinated than conventional agri-food supply chains. The result could be similar to the supply chain of Nexera Canola which is discussed in chapter four.

6.2 Limitations and recommendations for further research

The primary objective of this thesis was to provide explanations of the three factors that could potentially cause a set back to commercialization of GM functional foods and tie them together. One limitation of attempting to work with all three factors was that it was not possible to conduct a deeper analysis of key factors due to time constraints. As a result, the recommendations for further research include more in depth research of specific factors.

The first recommendation is that research be conducted in more depth on food manufacturers' preferences regarding the risk they are willing to take in expanding their brand. Much of the literature regarding agricultural biotechnology and consumers has focussed on individual consumer preference. Although this is important, it is the food manufacturer that makes the decision on whether to expand their brand to include new products. Expanded research concerning food manufacturers would be valuable not only for analyzing GM functional foods, but also new food introductions in general.

Further, in regards to the heterogeneous consumer model in section 3.3, it is assumed that the market is competitive. In reality the market could have several different structures. Initially the GM functional food manufacturer might have monopolistic power, similar to that shown in the vertical market (Figures 3.1, 3.8 and 3.9). It was also

assumed that the national brand introduces the GM functional food. To adapt this model to be used in combination with the full vertical market model, it would have to be adapted to use strategic pricing rather than competitive. It would also be useful to analyse a situation where a new entrant to the industry introduces the GM functional food.

Another limitation is the use of hypothetical values in the simulation analysis. This study was limited to hypothetical values because it is analysing products that are not on the market. A recommendation would be to perform more in depth research and calculate more realistic values for the variables using consumer attitudes towards brands and food quality collected through stated preference surveys and/or revealed preference market data if new products are introduced. Also, it would be valuable to expand the model to include costs. The demand function for GM functional foods could easily be derived from the market shares[24] of the types of foods. When the demand and supply are combined, the scenarios necessary for the GM functional food to be successful could be calculated. The model could then be shocked by changes to the expected profit because of regulatory uncertainty. It would also be valuable to include a time variable into the simulation analysis to show the effects that time to regulatory approval has on the successful commercialization of a functional food. Also, the effect of increases in transaction costs and reductions to demand could be examined.

Although the problem of multiple bilateral monopolies was mentioned in the thesis, it was not explicitly modelled. If a single bilateral monopoly negotiation leads to a sub-optimal solution, a supply chain with multiple bilateral monopolies could come to an agreement that is far from the optimum. Paradoxically, a supply chain with multiple

[24] Recall that demand for an individual product in this model is equal to market share multiplied by the total demand for that type of food.

bilateral monopolies would likely need more rent to distribute in order to satisfy the firms involved. This leads to a potential hold-up problem, where there is no solution to make the supply chain work. Further modelling of this problem would be useful and possibly fill a void in the literature.

Finally, there are some interesting policy implications that emerge when discussing functional foods, especially in Canada, where health care is publicly funded. Malla et al. (2005) estimated the savings to Canada's health care system resulting from a conversion to Natreon canola oil to be CDN $1.12 billion per year because of a reduction in cardiovascular disease. There may be a market failure because consumers must pay a premium to consume the functional foods. In a publicly funded health care system, some of the costs of poor health are borne by the taxpayers. The policy implications of this problem as it relates to functional foods in general could be discussed in future research. Malla et al. (2005) recommend product labelling legislation to reduce information asymmetry, and also a pigovian tax on unhealthy foods or subsidies on healthy foods to encourage consumption. These issues were not discussed in this thesis, but would be an interesting area of future research.

6.3 Conclusions

After examining the government regulatory uncertainty, consumer aversion and brand equity issues, and the issues related to gaining access to intellectual property, the conclusion can be made that all three factors exist throughout the supply chain for GM functional foods. When the explanations and theoretical model of the three factors were

examined separately there was evidence that they could lead to a delay to the commercialization of GM functional foods.

When these factors are combined, there is a lot of uncertainty for stakeholders within the supply chain to take into consideration. There is also evidence that the lifescience firms that specialize in agricultural biotechnology have realized that it might be more valuable to make modest claims. A look at the literature provided on the websites of firms like Monsanto and Pioneer Hi-bred International (DuPont) shows that the products currently being developed are for simple improvements such as soybeans that produce oil that does not have to be hydrogenated.

Overall, the commercialization of GM functional foods will be a challenge to all involved. In order to compensate those within the supply chain for dealing with increased government regulatory uncertainty, high transaction costs, risk to firms' brand equity and specialized methods of production and handling; the consumers are going to be asked to pay a premium for the food. For consumers to be willing to pay this premium, the product will have to provide a valuable health trait that is not available in a conventional form at a lower price. The balance between the extra costs and premium price will be important to avoid set backs to commercialization. In the case of the food manufacturer, the benefit will have to be high in order to take a risk expanding their brand to include a GM functional food that has the potential to lead to controversy.

These factors combine to generate a realistic view of the potential for agricultural biotechnology to contribute to the health of consumers. The lifescience firms have the technical capability to develop foods that provide consumers with large health benefits. However, the factors contributing to the set back have led to less drastic goals in the

development of agri-food innovations. At least in the foreseeable future, consumers will not receive the benefits from agricultural biotechnology that were promised at the outset of this agricultural biotechnology revolution.

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APPENDIX A

EXPLANATION OF SIMULATION ANALYSIS

The simulations were performed in Microsoft Excel using the Solver function, as was explained previously. Prior to the three good market, which includes the GM tomato paste, a two good scenario is developed in both the 50-50 and 70-30 scenarios. The variables and parameters from equations 9 and 10 were used in the two good set up. The market share values (S_A and S_S) were also set to be equivalent to equations 9 and 10.

In each case, solver was set up to give the desired market share of conventional tomato paste (either 0.5 or 0.7). The market share of the substitute also changed as desired with this command to sum to 1.0. The tomato paste prices were inserted into the model. The base utilities and discount factors were the cells that were changed in order to provide the desired market shares.

Restrictions were put into place in order to obtain results that were consistent. First, the sum of S_A and S_S was set equal to 1 and the value of the respective market shares were restricted to be between 0 and 1. The values of the base utilities ($\overline{U}_A$ and $\overline{U}_S$) were restricted to be positive. Finally the discount factors λ and γ were restricted to be between 0 and 1. The results of the Solver model are displayed in Table 3.1.

These results were then inserted into a model with three goods. This model used the variables and parameters from equations 12, 14 and 15. Throughout the two scenarios using three goods, the values of $\overline{U}_S, \overline{U}_A$, PS, PA, λ and γ were kept constant. The variables $\overline{U}_F$, PF and μ were changed in Solver to attain the desired market share (S_F) of 0.1. The other market shares of the conventional and substitute tomato pastes (S_A and S_S) adjusted accordingly so the three market shares summed to 1.

The same restrictions were used in the three good scenario as were used in the two good cases. However, there were additional restrictions required to obtain a solution. The base utility of the functional tomato paste ($\overline{U}_F$) was restricted to be greater than 0. The discount factor (μ) and the market share (S_F) of the functional food were restricted to be between 0 and 1. The discount factor of the functional food (μ) was restricted to be the same or less than that of the conventional tomato paste (λ), and the base utility of the functional tomato paste ($\overline{U}_F$)was restricted to be at least as large as the base utility of the conventional tomato paste ($\overline{U}_A$).

After the base situation was developed that provided the desired functional tomato paste share of 0.1, the sensitivity was performed simply by changing the desired variable or parameter and observing the effect on the respective market shares. In situations where the test was to determine what value would give a market share (S_F) of 0 (Situations 4, 6, 9, 13, 15, 18), the variable of interest was set to change in Solver so that the value of S_F was 0.